STATEWIDE RISK ASSESSMENT METHODOLOGY FOR THE NORTH CAROLINA NATURAL HAZARD MITIGATION PLAN

by

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1 EXECUTIVE SUMMARY

This document describes the methodology used to complete the Risk Assessment section of North Carolina's statewide natural hazard mitigation plan. Several models exist for risk assessments at the community and state level. This methodology uses the statewide assessment of Rhode Island (Odeh, 2002) as a model, which quantifies vulnerability for multiple hazards and exposures by census tracts of their state. However, larger states, such as North Carolina, have a greater distribution and diversity of natural hazards than those examined in the Rhode Island assessment. Thus, this document also describes the modifications that were made to the Rhode Island model in order to complete the risk assessment at a larger statewide scale.

Discussion with meteorological and geological experts from across North Carolina identified a total of forty-two natural hazards to include in the risk assessment. Each hazard was assigned a score by these experts based on its scope, frequency, intensity, and destructive potential according to climate region. Exposures were also identified and include the six categories of population, structures, economic activity, critical facilities, transportation and environmental exposure. Each exposure category received a score by county from data made available through the Federal Emergency Management Agency (FEMA) HAZUS-Multi Hazard database, the North Carolina Center for Geographic Information and Analysis (NC CGIA) Hazard Pro database, and the North Carolina Department of Commerce Economic Development Information System (EDIS). The score combinations were then completed to create multiple spatial representations of natural hazard and exposure vulnerability hotspots across the state at the county level.

The final scores serve as a qualitative assessment of the total vulnerability to guide policy formulation of the hazard mitigation plan. The information contained in the assessment will be made available to municipal and county mitigation planning efforts in hazard mitigation and provide information to the public and other state, regional and county organizations about natural hazards in North Carolina. The methodology used in this assessment may also be useful to serve as a model for other larger states completing risk assessments across the country.

2 INTRODUCTION

2.1 Background

In the year 2000, the United States Congress passed the Disaster Mitigation Act of 2000 (DMA) into law as a revision of the Robert T. Stafford Disaster Relief and Emergency Assistance Act. The purpose of the DMA is to lessen the vulnerability of citizens to the myriad of natural hazards affecting the United States through the strengthening of mitigation efforts at the state and local levels. Section 322 of the DMA conditions that each state creates a natural hazard mitigation plan to be submitted for approval to the Federal Emergency Management Agency (FEMA) by the fall of 2004. A draft of North Carolina's "322 Plan", or the statewide hazard mitigation plan, has been reviewed by FEMA and returned with suggestions for improvement.

The Risk Assessment, to be contained as Appendix A of the North Carolina Enhanced State Mitigation Plan, provides an identification, description and assessment of the major natural hazards that impact North Carolina. In this context, vulnerability is the extent to which people and property will be adversely affected by a given hazard. The state's degree of vulnerability depends upon the risk of a particular natural hazard occurring (including such factors as scope, frequency, intensity, and destructive potential), as well as the amount of the population, structures and facilities, economic activity, or environmental resources that are exposed. Vulnerability levels are also affected by mitigation policies that are in place to reduce hazard impacts, as well as by policies that may exacerbate the state's vulnerability (albeit inadvertently) by facilitating development in hazardous areas. It is the purpose of the risk assessment to provide the best available information for use in hazard mitigation policy formulation for the state of North Carolina.

The state of North Carolina, through collaborations between the Division of Emergency Management, University of North Carolina – Chapel Hill (UNC-CH) Hazard Mitigation Planning Clinic and the Center for Geographic Information Analysis (CGIA), has completed substantial work towards meeting and exceeding the Section 322 requirements for the Risk Assessment. In the spring of 2003, the Hazard Mitigation Planning Clinic of the Department of City and Regional Planning at UNC – CH accepted the responsibility for the completion of the lesser hazards risk assessment section of the 322 Plan. During the summer of 2003, a great deal of work was done towards the completion of the risk assessment. A methodology was conceived for the vulnerability assessment of the large number of natural hazards that can affect the entire state of North Carolina. Additionally, work was started on the definitions, descriptions, and hazard scoring components of the assessment. During the fall of 2003 and winter of 2004, the remaining components of the assessment methodology (an exposure assessment and total vulnerability score generation) were completed. The final risk assessment document was given to the Division of Emergency Management in March, 2004. However, the document does not include the methodology devised for the completion of the risk assessment.

2.2 Purpose

The purpose of this supplement is to provide documentation on how to go about performing the methodology used for the North Carolina risk assessment. This methodology document is a separate document from the risk assessment produced for the Division of Emergency Management. However, it serves as a compliment to the 322 Plan risk assessment as well as a tool for future assessments undertaken by the state. Thus, this document will provide FEMA and the Division of Emergency Management with a thorough description of the steps taken by the Hazard Mitigation Planning Clinic for this particular risk assessment, but also will provide guidance to North Carolina for future state level revisions of the risk assessment.

Several models exist for risk assessments at the community and state level. This methodology uses the statewide assessment of Rhode Island (Odeh, 2002) as a model, which quantifies vulnerability for multiple hazards and exposures by census tracts of their state. However, larger states, such as North Carolina, have a greater distribution and diversity of natural hazards than those examined in the Rhode Island assessment. Thus, this document also describes the modifications that were made to the Rhode Island model in order to complete the risk assessment at a larger statewide scale.

It is important to note that this methodology not only goes above and beyond the Section 322 provisions, but is unlike any other attempts by other states at such a large scale. Other states also must meet the provisions of the DMA and may be interested in the use of this document in performing similar assessments.

3 METHODOLOGY

3.1 Overview of approach

The methods used in this assessment result in a qualitative measure of the vulnerability of natural hazards. It involves the calculation of three scores: the hazard score, the exposure score, and the total vulnerability score. The total vulnerability score for each county is the product of the sum of all hazard scores and the sum of all exposure scores, as stated in the following formula:

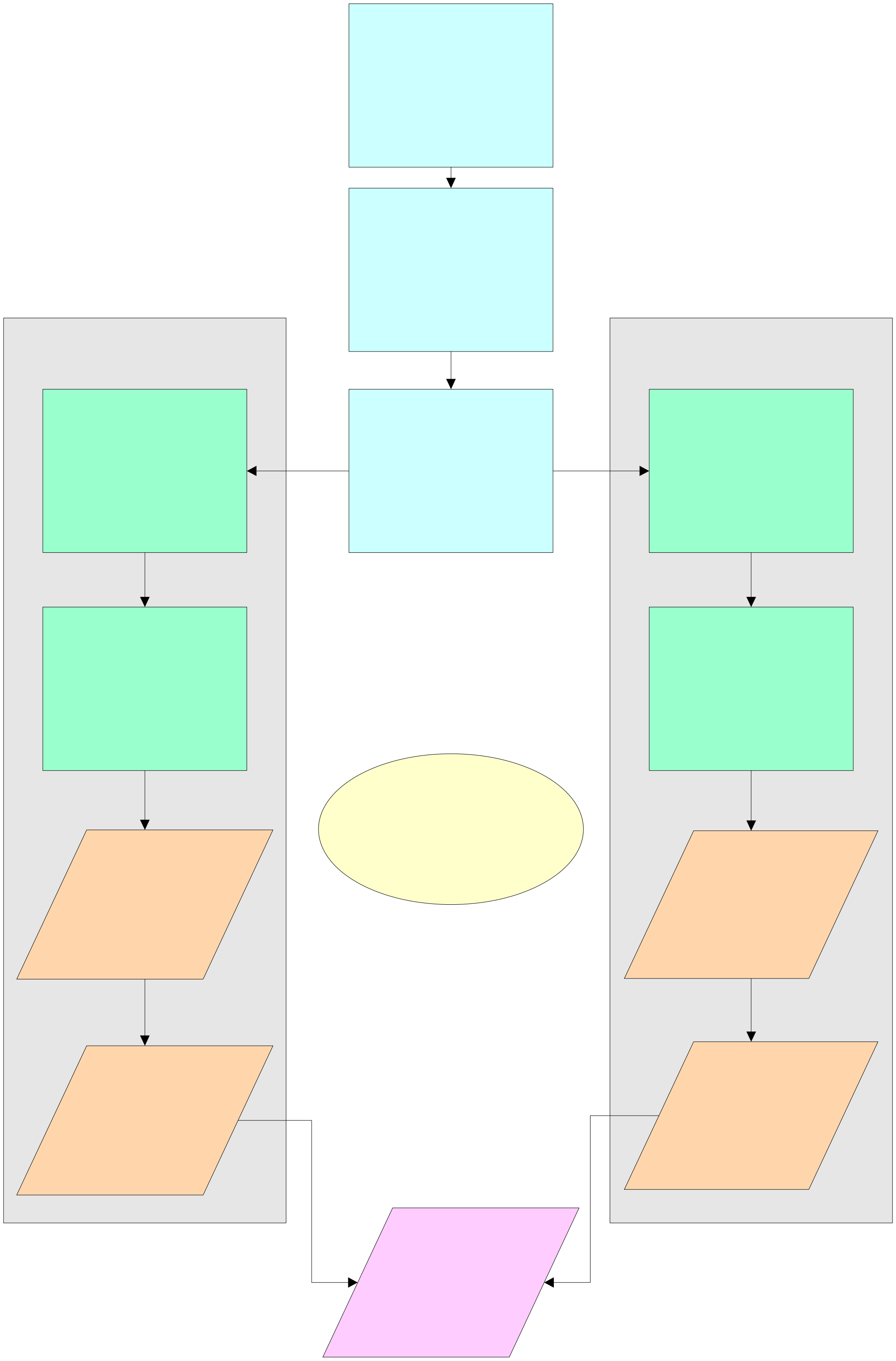
Total Vulnerability = Total Hazard Score x Total Exposure Score

A flow chart of the overall process used in this methodology to achieve the total vulnerability score can be found in *Flow Chart 1* below. The first step involved the determination of the risk assessment goals. The main goal of the North Carolina risk assessment was to meet and exceed the requirements of the Disaster Mitigation Act of 2000. To this end, the results produced a qualitative measure of vulnerability for comparison and analysis that would be useful in guiding the policy formulation of the state hazard mitigation plan. The process then involved the determination of the proper scale at which to assign the vulnerability scores. The selected scale for the North Carolina assessment is at the county level. The hazard scores, in particular, are based on defined climate and geographic regions of the state, which are described in Section 3.2.

The next steps involved the gathering of data and calculation of scores for both the hazard and exposure sides of the vulnerability equation. The hazard scores and exposure scores involve several underlying calculations. Each of the 100 counties in North Carolina received a hazard score for each of the state's identified hazards. The identified hazards are then summed to obtain the total hazard score for each county. There is also an exposure score for each county based on six categories of exposure: population, economic activity, critical facilities, structures, transportation and environment. The six exposure scores are summed to obtain the total exposure score for each county. The product of the total scores result in a numerical value for each county that can be compared across all counties as to its vulnerability.

The hazard score calculations are discussed in more detail in Section 3.3 and the exposure score calculations are discussed in Section 3.4. A discussion of the total vulnerability score and its possible variations follows in Section 3.5.

Flow Chart 1: The Generalized North Carolina Risk Assessment Process



Hazard Score Proce

3.2 *Region identification*

The climate of North Carolina varies considerably from the mountainous region in the west to the eastern coastline. Average temperatures vary by as much as 20 degrees from west to east. Average annual precipitation is generally around 50 inches statewide, but in the mountains there are significant terrain-induced variations. The minimum statewide average annual precipitation is 39 inches in northwestern Buncombe County, while the maximum average precipitation is over 85 inches in southern Jackson County. In light of the west-to-east gradient in climate variability due to topography (and proximity to the Atlantic Ocean) coupled with the north-to-south gradient in temperature due to latitude, North Carolina has been divided into eight climate divisions for purposes of long-term climatological assessments (Guttman and Quayle, 1996). These climate divisions are considered relatively homogeneous in their long-term climatology.

These climate divisions were applied to the hazard vulnerability scoring system with one adjustment. The three coastal climate divisions (6-8) were subdivided into coastal plain and coastal regions (*Table 1, Figure 1*). The coastal climate regions have significant differences in terms of differences in elevation and proximity to the coastline. Counties in the coastal plain do not experience the same natural hazards as would those directly along the coast (for example, coastal erosion). The designations of the twenty coastal counties were made according to those made by the Coastal Area Management Act of North Carolina. This adjustment to the geographic divisions was approved by the hazard experts for the purposes of the risk assessment. A listing of the counties in each region can be found in *Table 2.*

Table 1: North Carolina Hazard Region Geographic Divisions

North Carolina Risk Assessment Geographic Divisions		
Climate Region	***Division Name***	***Number of Counties***
1	Mountain 1	17
2	Mountain 2	8
3	Piedmont 3	13
4	Piedmont 4	10
5	Piedmont 5	11
6	Coastal Plain 6	9
7	Coastal Plain 7	4
8	Coastal Plain 8	7
6	Coastal 6	5
7	Coastal 7	5
8	Coastal 8	11

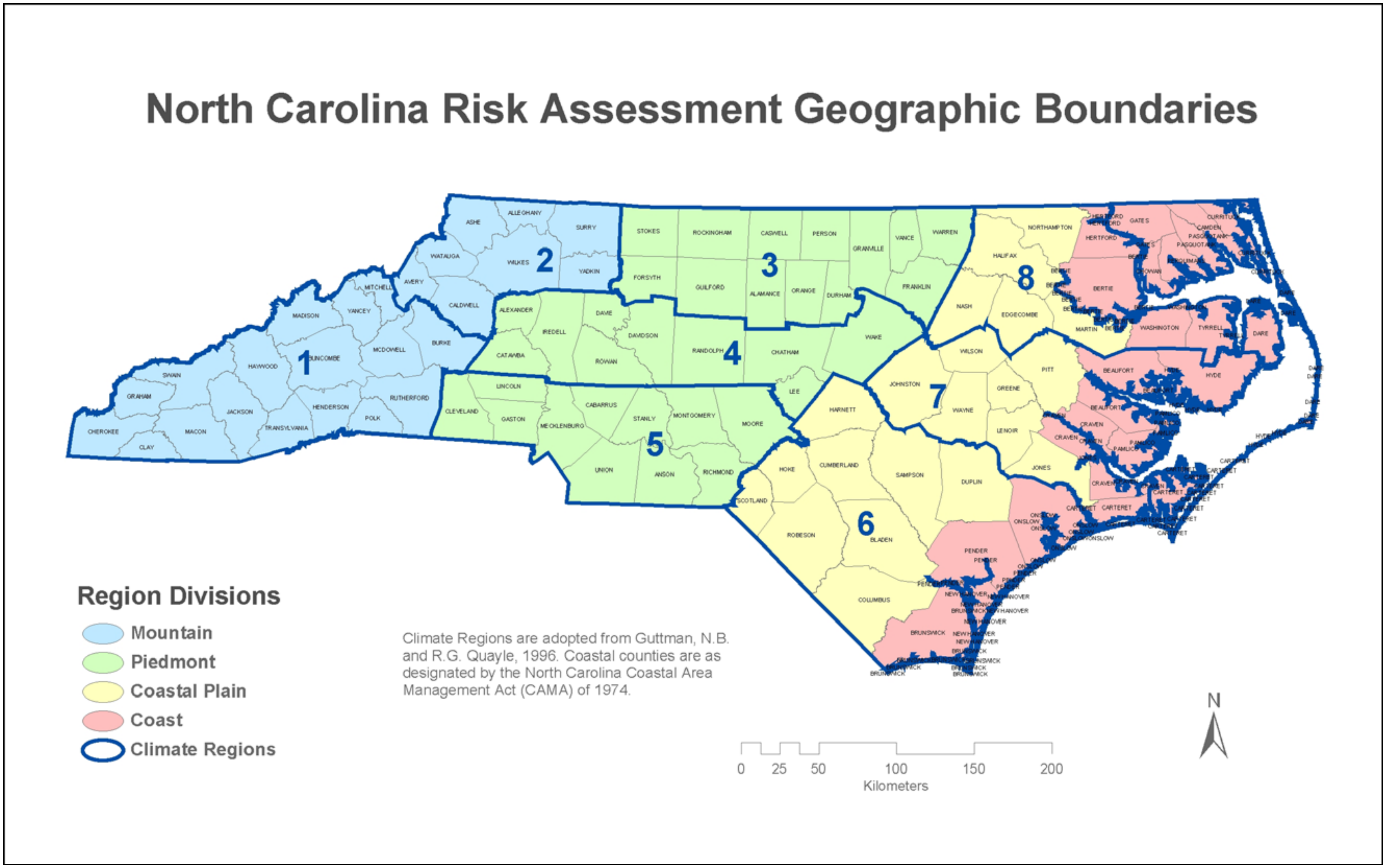


Figure 1: North Carolina Hazard Region Divisions

Table 2: North Carolina Counties per Hazard Region

Counties of North Carolina by Risk Assessment Region								
Mountain 1		***Mountain 2***	***Piedmont 3***		***Piedmont 4***		***Piedmont 5***	
Buncombe	Madison	Alleghany	Alamance	Rockingham	Alexander	Wake	Anson	Stanly
Burke	McDowell	Ashe	Caswell	Stokes	Catawba		Cabarrus	Union
Cherokee	Mitchell	Avery	Durham	Vance	Chatham		Cleveland	
Clay	Polk	Caldwell	Forsyth	Warren	Davidson		Gaston	
Graham	Rutherford	Surry	Franklin		Davie		Lincoln	
Haywood	Swain	Watauga	Granville		Iredell		Mecklenburg	
Henderson	Transylvania	Wilkes	Guilford		Lee		Montgomery	
Jackson	Yancey	Yadkin	Orange		Randolph		Moore	
Macon			Person		Rowan		Richmond	

Coastal Plain 6	***Coastal Plain 7***	***Coastal Plain 8***	***Coastal 6***	***Coastal 7***	***Coastal 8***	
Bladen	Greene	Edgecombe	Brunswick	Beaufort	Bertie	Chowan
Columbus	Johnston	Halifax	New Hanover	Carteret	Camden	Dare
Cumberland	Jones	Martin	Onslow	Craven	Currituck	
Duplin	Lenoir	Nash	Pender	Hyde	Gates	
Harnett	Pitt	Northampton		Pamlico	Hertford	
Hoke	Wayne				Pasquotank	
Robeson	Wilson				Perquimans	
Sampson					Tyrrell	
Scotland					Washington	

3.3 Hazard Score

The hazard score was formulated in order to quantify the natural hazard vulnerability of each county to each identified hazard. This score can also be used to show how the vulnerability of each county compares with the other counties of the state. The hazard score focuses just on the identified hazards and their impact on a county regardless of the number of structures, percentage of population, or type of economic activity exposed. Alternatively, the exposure score (Section 3.4) focuses on quantifying these human aspects of total hazard vulnerability versus the ability of a natural hazard to have an impact in the first place.

The hazard score was computed after several essential components of the risk assessment were completed as a foundation. First, it was necessary to identify the hazards that were to be assessed. The process taken by North Carolina is further described in Section 3.3.1 and Section 3.3.2 below, which meet the requirements described in 44 CFR 201.4(c)(2)(i). (Please see Appendix A for the complete listing of applicable requirements). Then, the identified hazards were defined and described as to their possible effect and historical occurrence in North Carolina. This process is described in Section 3.3.3 below and meet the FEMA Region IV requirements described in 44 CFR 201.4(c)(2)(i) when combined with the hazard score results. The scoring procedure is further described in Section 3.3.4 through Section 3.3.6.

3.3.1 Hazards Identified

Forty-two natural hazards were identified for the state of North Carolina. These 42 hazards have been divided into two categories and nine groups for ease of organization, interpretation and reference. The categories split the hazards into "Greater" and "Lesser" hazard categories. The Greater Hazards are those identified as having the most potential impact on the state of North Carolina in the past and in the future. The Lesser Hazards are still hazards of significant concern, but have not had as large of an impact on the entire state in the past, or in the anticipated future. The Greater Hazards include: Floods, Earthquakes, Hurricanes/Coastal Hazards, Wildfire, and Severe Winter Weather. The Lesser Hazards include: Dam Failure, Drought, Geological, and Tornado/Severe Thunderstorm. *Table 3* lists all of hazards included in the Greater Hazards category. *Table 4* lists all of hazards included in the Lesser Hazards category.

Table 3: Listing of Identified Greater Natural Hazards by Group Designation

Greater Hazards Category – Listing of Identified Hazards by Group		
Flood	***Earthquake***	***Wildfire***
Floods	Earthquakes	Wildfire
Hurricanes and Coastal Hazards		***Severe Winter Weather***
Hurricanes	Nor'easters	Severe Winter Weather
Hurricane - Storm Surge	Nor'easters - Storm Surge	Severe Winter Weather - Freezing Rain
Hurricane - High Wind	Nor'easters - High Wind	Severe Winter Weather - Snowstorms
Hurricane - Torrential Rain	Nor'easters - Severe Winter Weather	Severe Winter Weather - Blizzards
Hurricane - Tornadoes	Tsunami	Severe Winter Weather - Wind Chill
Rip Current	Coastal Erosion	Extreme Cold

Table 4: Listing of Identified Lesser Natural Hazards by Group Designation

Lesser Hazards Category – Listing of Identified Hazards by Group			
Dam Failure	***Drought***	***Geological***	***Tornado/Thunderstorm***
Dam Failure	Drought	Debris Flow/ Landslide	Severe Thunderstorm
	Drought - Agricultural	Subsidence	Severe Thunderstorm - Hailstorm
	Drought - Hydrologic	Acidic Soil	Severe Thunderstorm - Torrential Rain
	Heat Wave	Geochemical-related	Severe Thunderstorm - Thunderstorm Wind
		Mine Collapse	Severe Thunderstorm - Lightning
		Sinkholes	Tornado
		Expansive Soil	Tornado - Waterspout
			High Wind
			Fog

3.3.2 Documentation of the hazard identification process

Hazard identification for the risk assessment took place in an expert panel meeting on June 19, 2003. The hazard identification process included a total of eleven natural hazard experts from across the state (*Table 5*) that provided a comprehensive representation of knowledge across all natural hazards. At the

June 19 meeting, the natural hazard experts were charged with the responsibility of identifying which natural hazards are of concern for North Carolina.

A large number of natural hazards were discussed before the final natural hazards for the risk assessment were identified and grouped. The experts were divided into meteorological and geological sessions to determine a list of hazards to include in the risk assessment. In order to make these determinations, they provided preliminary information on previous occurrences, projections of future occurrences, and geographic location of hazard events, which were later revised and supplemented with additional background research (Section 3.3.3).

Table 5: Listing of hazard experts by specialty

Experts Consulted on June 19, 2003 (and on other occasions)		
Hazard Experts	***Organization***	***Specialty***
Stanford Adams	NC DENR, Forest Resources Division (State Forester) Director	wildfire
Ryan Boyles	NC State University Climate Office	meteorology
Tami Idol	NC DENR, Land Resources Management Division	dam failure/geology
Carl Johnson	NC Forest Service, Forest Resources Division	wildfire
Jeff Orrock	NOAA	meteorology
Margery Overton	NC State University	coastal erosion
Peter Robinson	University of NC, Geography Department, Former NC climatologist	meteorology
Kenneth Taylor	NC Division of Emergency Management, Director	earthquakes/geology
Steve Underwood	NC DENR, Division of Coastal Management	coastal hazards, forestry
Other Experts Consulted (but unable to attend June 2003 expert meeting)		
Hazard Experts	***Organization***	***Specialty***
Jeff Reid	NC DENR, Land Resources Management Division	geochemical hazards/geology
Jim Simons	NC DENR, Land Resources Management Division Director, State Geologist	geology

Some hazards were excluded from the risk assessment by the experts. At the June 19 meeting, volcanoes were discussed among the list of natural hazards, but were excluded from the analysis. It was determined by the experts that volcanoes are not a natural hazard of concern in North Carolina. According to expert geologists attending the meeting, volcanoes have not occurred in North

Carolina for over one million years and there are no longer any active volcanoes in North Carolina (Ken Taylor, *personal communication*, 2003). At subsequent individual meetings with the hazard experts, avalanche hazards were also excluded from the analysis. Avalanche was first divided from Debris Flow/Landslides to discuss and score its scope and frequency of occurrence separately. Due to the elevation of the mountains of North Carolina, it was determined by geological experts that there was not enough snow for an avalanche hazard to occur and it was eliminated from the analysis.

The hazards in Table 3 and Table 4 were officially identified as hazards of valid concern for North Carolina. The meteorological hazard experts recommended the placement of several hazards into sub-hazard status as a way to clarify the overlap between hazards on such an extensive list. Each of the sub-hazards was independently identified as a hazard for North Carolina, but the experts determined that several of the identified hazards would be more appropriately evaluated in terms of the causal hazard only.

For example, in the Hurricane/Coastal Hazard category, the hurricane hazard has four sub-hazards. These include high wind, tornadoes, torrential rain, and storm surge. High wind, tornadoes, and torrential rain are all hazard events that could occur as a part of, or a result of, a hurricane. However, they could also occur completely independent of a hurricane. Thus, they are treated as sub-hazards for hurricanes and independent hazards in other categories, such as tornado/severe thunderstorms. Storm surge will not occur without the occurrence of a hurricane or nor'easter, which is why it is not considered its own hazard individually; rather, it is included as a sub-hazard of hurricanes and nor'easters. Many hazards do not have sub-hazard, but in the cases where they do, the experts felt strongly about their placement.

3.3.3 Hazard Descriptions

The hazard descriptions were an important foundation for the rest of the risk assessment. These descriptions compiled the most recent and detailed information available on all of the identified hazards and are comprised of the following sections for each hazard: definition, description, historical occurrence, and hazard score. All of the descriptions can be found in the actual risk assessment document, "Section 2: Hazard Descriptions and Scores". The majority of the definition, description and historical occurrence information was gathered from the National Oceanic and Atmospheric Administration (NOAA)

National Climatic Data Center (NCDC, 2001) website, although many other sources were used that were primarily internet based. Internet search engines were used for general searches of each hazard, which lead to further information gathering on the internet and in the literature. All of the sources of information for the hazard descriptions are included in the actual risk assessment document and are too great in number to list here. The hazard experts viewed preliminary versions of the descriptions and also added in sources of information where they thought appropriate. Many of the historical occurrence accounts are lengthy, but provide a valuable source of information about the scope, frequency, intensity and destructive potential of each hazard. The hazard score was also provided at the end of the description section for each hazard in the form of a county level map. The scores were generated from these descriptions and discussion with experts, as is detailed in the next section (Section 3.3.4).

3.3.4 Hazard scoring procedure: The Matrix

The scoring system was completed for all hazards by the hazard experts *(Table 5)* over a seven month period. Scores were assigned to each county according to hazard region (*Figure 1, Table 1*) and can be viewed in terms of their spatial distribution in the last section of each hazard discussion. The hazard score evaluates each hazard based on the following criteria: scope, frequency of occurrence, intensity and destructive potential. Each of these criteria was defined and scored as follows:

- ***Scope*** is defined as the geographic extent of each hazard. Each region received a score of 0 or 5 for each hazard, where 0 = no occurrence of the hazard and 5 = occurrence of the hazard. Scope is scored in a binary fashion because the experts were asked to determine, based on the future expectations of the hazard for that region, whether or not it was possible for that hazard to take place on a yes or no basis.

- ***Frequency of occurrence*** is defined as the expected repetitive nature of a particular hazard in each hazard region. The expected return periods were defined and scored as follows:

Score	Frequency	Score	Frequency
5	1 event/1 year	2	1 event/30-99 years
4	1 event/ 2-4 years	1	1 event/100+ years
3	1 event/ 5-29 years		

- ***Intensity*** is defined as the average strength of each hazard in a representative hazard region as compared to the average strength of that same hazard in the continental United States. Where available, existing scoring schemes were used and translated to a 1 - 5 range scoring scale (for example: Saffir-Simpson Hurricane Scale). Where unavailable, the hazard experts used their best judgment, on a per hazard basis, as to how strong each hazard would score on a 1- 5 scale, with 3 being an average score. The scores in these cases are intended to provide a comparison to the strength of the same hazard type taking place in other parts of the United States. For example, no scale was available for application to the wildfire hazard, but the experts felt that in comparison to the rest of the US, the coastal regions had just as high of intensity of wildfires as any where else in the nation. Thus, the coastal regions received a 5. The wildfires in Mountain Region 1 were decided to be of average intensity in comparison to others across the nation, resulting in a score of 3.

- ***Destructive potential*** is defined as the ability of a hazard to strike at full intensity and how severe the intensity will be in comparison to the other hazards that were identified for North Carolina. Destructive potential is similar to intensity, but focuses on the comparison between hazards, rather than among the same hazard. It also provides a way of ranking the strength of hazards within North Carolina. A score of 5 was given to hazards with the most destructive potential and a score of 1 was given to the hazards with the least destructive potential. Scores between 1 and 5 were based on the opinions of the experts as to how the particular hazard compared to the other identified hazards.

Each of the 42 hazards received a score from 0 - 5 for each of the four hazard score criteria. These four scores were then multiplied to calculate the hazard score for each individual hazard, as shown by the following formula:

Hazard Score = Scope x Frequency x Intensity x Destructive Potential

These individual hazard scores are the scores by county that are represented spatially in each hazard description of the risk assessment. All of the scores were represented in a Hazard Matrix, created in Microsoft Excel, which can be printed in large format for viewing purposes and would automatically update the hazard score equation upon any score revision. A copy of the formatted Hazard Matrix used for this assessment with the final scores for scope, frequency, intensity, destructive potential and hazard score can be found in Appendix B.

3.3.5 Hazard matrix scoring meetings with experts

Each of the scores for the categories described above was assigned by one or more hazard experts listed in *Table 5* for each of the 11 regions of North Carolina. The meetings to fill out the matrix were held separately from the initial expert panel meeting of June 19, 2003 and were held on an individual basis over a period of seven months. During the individual consultations, the hazards to be scored were determined ahead of time, allowing the expert to prepare any information that may be useful to the scoring process. This information was translated into the scores and included in the hazard descriptions where necessary. Appendix C contains notes taken during these meetings as to provide documentation of the decision making process for the hazard scores. A large format copy of the Hazard Matrix (Appendix B) and map of the Hazard Regions (*Figure 1*) were used during the meetings and were extremely helpful to have on hand for discussion purposes. The experts could write the scores directly on to the Matrix and look at other scores for comparison. A total of five individual meetings were held in order to complete the Hazard Matrix in January of 2004.

3.3.6 Combined hazard scoring procedure

Once all of the scores were entered into the Hazard Matrix, it was then possible to calculate the total scores and display the scores several ways. The total hazard score, as calculated using the formula stated above in Section 3.3.4, was first mapped for each of the 42 hazards. The hazard scores were mapped by joining the scores, which were exported from Excel as a database file and converted to an info file in ArcGIS, to a CGIA shape file of the counties by their Census FIPS code (Please see Appendix I for more details on this process). The scoring range was between 0 – 625, where a score of 0 means that the hazard does not take place in that county/region and a score of 625 represents a maximum score of 5 for each of the four hazard criteria. An example individual hazard score map is shown in *Figure 2* below. For all of the 42 individual hazard score maps, please see the completed risk assessment. A summary of scores for all hazards by region is included in Appendix D.

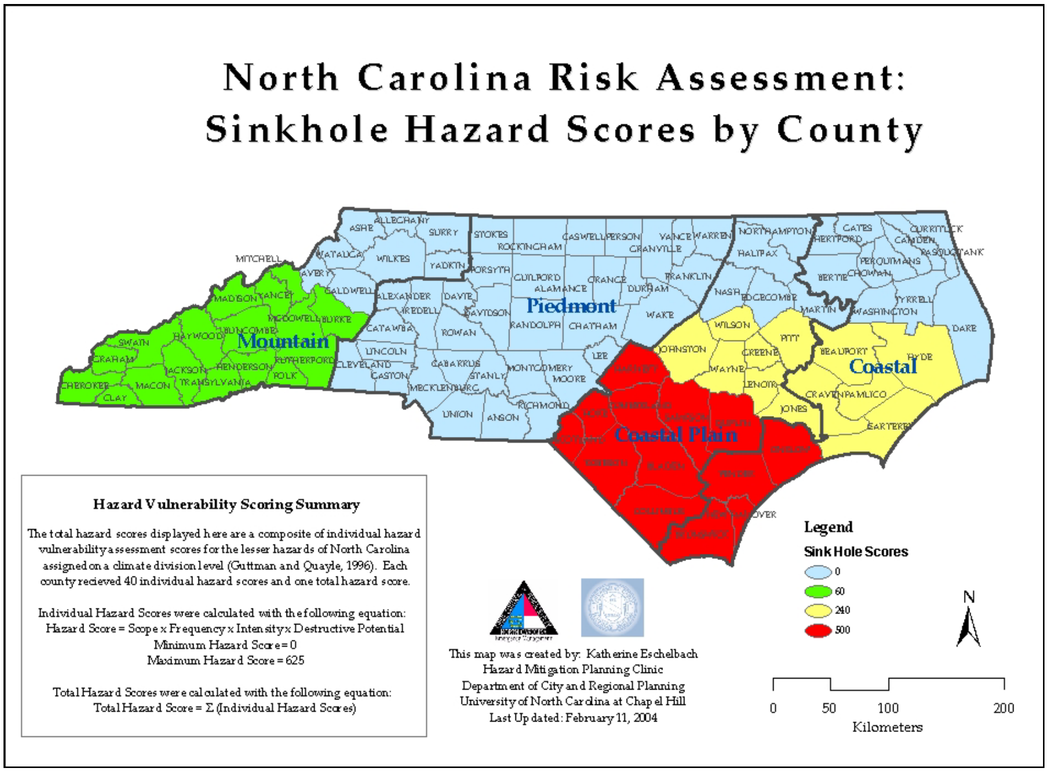


Figure 2: Example Individual Hazard Score Map

Although the maps for each hazard are extremely useful as background information on each hazard in terms of its scope, frequency of occurrence, intensity, and destructive potential, it is also possible to aggregate the scores for multiple hazards in each group to determine the score for the hazard groups as a whole. The maps for each hazard group (the Greater hazards group and Lesser hazards group, *Tables* 3 and 4, respectively) are the spatial representations of the composite scores for each group and are useful in streamlining the information load of the large number of natural hazards identified. For example, the geological hazard group hazard scores were summed together and normalized according to the following formula:

Total Geological Hazard Group Score = (Debris Flow score + Subsidence Score + Acidic Soil Score + Geochemical-related Score + Mine Collapse Score + Sinkholes Score + Expansive Soils Score) / 7

Additionally, the total geological hazard group score could be added to the other subcategory scores to create a total lesser hazard group score:

Total Lesser Hazard Score = (Dam Failure Score + Drought Score + Tornado/Thunderstorm Score + Geological Score) / 4

These composite maps are normalized by the number of hazards in each group; therefore, the scores have undergone an averaging effect, resulting in lower scores than may be found in the individual hazard score maps. It is important to reference each hazard score map individually if there are specific questions about a particular individual hazard. An example of the group composite for the geological hazards is shown below in *Figure 3*.

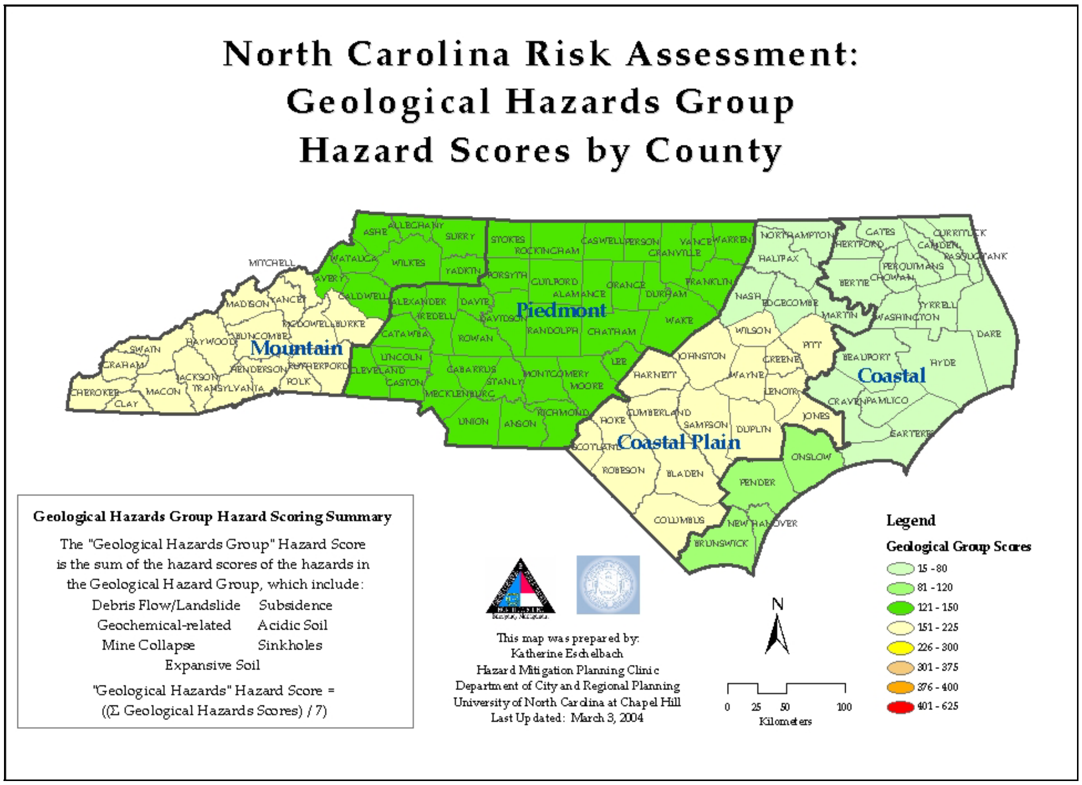


Figure 3: Example Hazards Group Composite Score Map

Additionally, the composite scores for the two hazard groups can be summed for a total composite hazard score per county. This score is the total of all scores for the 42 hazards that could possibly affect that county. The total hazard scores for all hazards (excluding earthquakes and floods) are shown below in *Figure 4*.

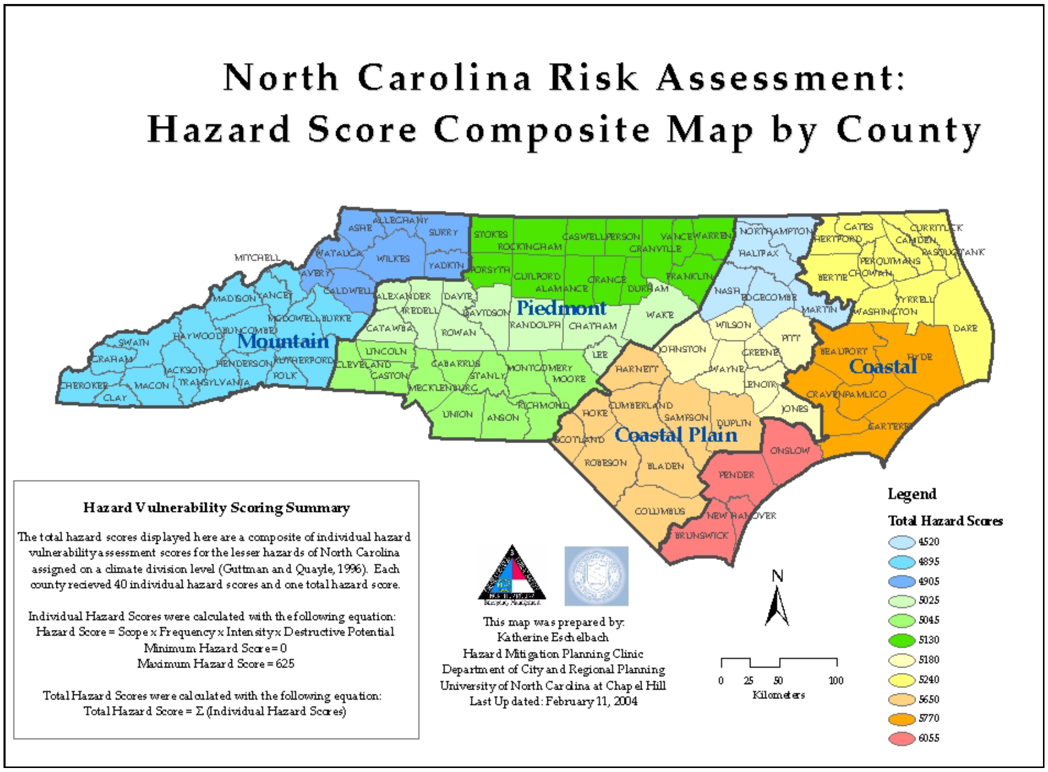


Figure 4: Total Hazard Score Composite Map

The total hazard score is then used as a multiplier of the total exposure score to reach a determination of total vulnerability per county. The process of reaching the total vulnerability score is discussed in Section 3.5. Before the total vulnerability score can be determined for each county, the total exposure score must be calculated, as described in Section 3.4 below.

SUMMARY OF HAZARD SCORE PROCEDURE:

- Identify, define, and describe hazards
- Conduct expert meetings to complete the matrix and obtain a hazard score for each individual hazard according to geographic region
  - See Appendix B for the complete matrix
  - See Appendix C for expert meeting notes
- Individual hazard score = Scope x Frequency x Intensity x Destructive Potential
  - Minimum score = 0, Maximum score = 625 for each hazard
  - See Appendix D for all individual hazard scores by region
- Hazard Group score = Σ Individual hazards within the hazard group
- Total Hazard score = Σ all hazard scores
- Scores are entered into a GIS system and mapped for each individual hazard, hazard group, and all hazards as a composite
  - See Appendix I for a description of GIS processing steps

3.4 *Exposure Score*

Vulnerability is a measure not only of the natural hazards that affect the state, but also a measure of what is exposed to those natural hazards. The exposure score was formulated in order to quantify the natural hazard vulnerability of each county to each identified exposure. This score can also be used to show how the exposure vulnerability of each county compares with the other counties of the state. The exposure score focuses just on the number of structures, percentage of population, or type of economic activity exposed, rather than the meteorological or geological variations per county. In this way, the exposure score quantifies the human aspects of total hazard vulnerability.

The exposure score was computed after several steps were completed as a foundation. First, it was necessary to identify the exposures that were to be assessed. The process taken by North Carolina is further described in Section 3.4.1 and Section 3.4.2 below, which meet the requirements described in 44 CFR 201.4(c)(2)(ii). (Please see Appendix A for the complete listing of requirements). Then, the identified exposures were classified according to the range of values contained in each exposure indicator and mapped to display the distribution of scores for each exposure category by county. The classification/scoring process is further described in Section 3.4.2.

3.4.1 Identified Exposures

Six categories of exposure were identified for the risk assessment: population, structures, economic activity, critical facilities, transportation, and environmental exposure. The exposure categories were identified through the accessibility of the best available data at a county level and were felt to give the best available representation of exposure types across the state. These categories were approved during a meeting with Division of Emergency Management staff and subsequent State Hazard Mitigation Action Group (SHMAG) meetings. Each category is composed of different indicators of that type of exposure (*Table 6*). These indicators were largely based upon the availability of state wide data. A more detailed reasoning behind the selection of each of the particular indicators is further described in the sections below.

Table 6: Exposure categories and data used in each category

Exposure Category	Data Indicators Used in Category
Population	the # of people per county (2000 Census)
Economic Activity	the # of employees per county for the following employment types: commercial, industrial, agricultural, governmental, and educational; the median household income per county
Structural	the # of structures per county for each of the following: residential, commercial, industrial, agricultural, religious, governmental, and educational; the # of residential structures built before 1970, between 1970-90, & after 1990
Critical Facilities	the # of facilities per county for each of the following: nuclear facilities, government facilities, hospitals, dams, military facilities, emergency operations centers, communications facilities, electric power facilities, natural gas facilities, fire stations, police stations, waste water treatment plants, potable water facilities
Transportation Facilities	the # of facilities per county for each of the following: airports, bus stations, highway bridges, highway tunnels, ports, railroad stations
Environmental	the # of facilities for each of the following: Hazmat sites, major NPDES dischargers, registered animal operations (swine, horse, poultry and cattle)

3.4.1.1 Category 1 - Population Exposure

Population was selected as an indicator of exposure in order to quantify the total number of people per household that could be exposed to hazards occurring in each county.

The population exposure category uses the population count of each county from the 2000 Census. The 2000 Census data was obtained from the Federal Emergency Management Agency (FEMA) Hazus-Multi Hazard (Hazus-MH)

Database (FEMA, 2003). Population data was then aggregated to the county FIPS code level for the scoring application process of this risk assessment.

3.4.1.2 Category 2 - Economic Activity Exposure

The count of employees per employment type was selected as an indicator of exposure in order to quantify the total number of people per employment type that could be exposed to natural hazards occurring in each county. Higher numbers of employees in a county correspond to higher levels of economic activity exposure. The median household income per county was also selected as an indicator of exposure in order to quantify the different levels of income that could be exposed to natural hazards occurring in each county. Higher levels of household income in a county correspond to higher levels of economic activity exposure. Aggregation of these indicators is the best measure of total economic activity for the state based on available data.

The economic activity exposure indicators include the count of employees for the following employment types: commercial, industrial, agricultural, governmental, and educational. The median household income per county was also included as an indicator of economic activity. The commercial indicator includes the aggregation of the following employment types: wholesale trade, retail trade, real estate, transportation and warehousing, finance and insurance, professional and technical services, administrative and waste services, health care and social assistance, accommodations and food services, and public administration. The industrial indicator includes the aggregation of all manufacturing and construction employment.

The population exposure category uses the data made available though the North Carolina Department of Commerce Economic Development Information System (NC Department of Commerce, 2004). Economic data contained in this database was made available at the county level over the EDIS website. It was then translated to the county FIPS code for the scoring application process of this risk assessment.

3.4.1.3 Category 3 - Structural Exposure

The count of structures per building type was selected as an indicator of exposure in order to quantify the total number of structures per building type that could be exposed to natural hazards occurring in each county. Higher numbers of these structures in a county correspond to higher levels of structural exposure. The residential construction year per county was also selected as an indicator of exposure in order to quantify the differences in residential building code restrictions that could be exposed to natural hazards occurring in each county. Earlier years of residential construction correspond to higher levels of structural exposure. Aggregation of these indicators is the best measure of total structural exposure for the state based on available data.

The structural exposure indicators include the count of structures for the following building types: residential, commercial, industrial, agricultural, religious, governmental, and educational. The residential indicator includes the aggregation of the following building types: single family dwelling, mobile home, multi family dwelling – duplex, multi family dwelling – 3-4 units, multi family dwelling – 5-9 units, multi family dwelling – 10-19 units, multi family dwelling – 20-49 units, multi family dwelling – 50+ units, temporary lodging, institutional dormitory, and nursing homes. The commercial indicator includes the aggregation of the following building types: retail trade, wholesale trade, personal and repair services, business/professional/technical services, depository institutions, hospital, medical office/clinic, entertainment and recreation, theaters, and parking. The industrial indicator includes the aggregation of the following building types: heavy industry, light industry, food/drugs/chemicals, metals/minerals processing, high technology, and construction. The government indicator includes only the Hazus-MH designated general services government facilities. The education indicator includes schools/libraries and colleges/universities. The residential construction year was also included as an indicator of economic activity. This indicator was aggregated into the following three categories: before 1970, between 1970 and 1990, and after 1990. According to the Office of the State Fire Marshal of North Carolina (Martin, *personal communication*, 2004), the first state building code was initiated in 1968. Major revisions to the state building code took place in 1993, 1997 and 2002. The divisions of the number of residences built within these three categories reflect the most drastic changes in the building code for the available residential data.

The structural exposure category uses the data obtained from the FEMA Hazus-MH Database (FEMA, 2003). Structural data collected from the Hazus-MH database was aggregated to the county FIPS code level for the scoring application process of this risk assessment. The structural indicators by building type classes were taken directly from the assigned HAZUS label classifications before they were aggregated for the scoring purposes of this risk assessment. The Hazus-MH codes, as well as their corresponding standard industrial codes, are listed and further described in the Hazus-MH Technical Manual, Chapter 3:

Inventory Data, Table 3-1 (FEMA, 2002a). The residential data was gathered from the US Department of Commerce Census of Housing for the Hazus-MH dataset. Dun & Bradstreet, a commercial supplier, collected all of the industrial and commercial data for the Hazus-MH building stock dataset (FEMA, 2002a).

3.4.1.4 Category 4 - Critical Facilities Exposure

The count of critical facilities was selected as an indicator of exposure in order to quantify the total number of critical facilities that could be exposed to natural hazards occurring in each county. Higher numbers of facilities in a county correspond to higher levels of critical facilities exposure. Due to the differences in influence of identified critical facilities, the indicators were divided into three subcategories. The subcategories are based on the spatial influence of the critical facility indicators at the state, regional, and county/local level. Scoring results for each subcategory were obtained and then aggregated to a total critical facilities exposure score. Aggregation of these indicators is the best measure of total critical facilities exposure for the state based on available data.

The critical facilities exposure indicators include the count of buildings for the following facility types: nuclear facilities, government facilities, hospitals, dams, military facilities, emergency operations centers, communications facilities, electric power facilities, natural gas facilities, fire stations, police stations, waste water treatment plants, potable water facilities. The medical care facilities indicator can be divided into three classes based on size: small, medium, and large. The dam indicator can be divided into three classes based on a designated vulnerability status of high, intermediate, and low. The military facilities indicator is an aggregation of the facilities of the following military branches: Navy, Air Force, and Army. The government facilities indicator includes only the Hazus-MH designated emergency response government facilities. The state level, regional, and county/local level subcategory divisions are displayed in *Table 7*.

Table 7: Critical facilities indicator subcategories

Critical Facilities Indicators by Subcategory		
State Level	***Regional Level***	***County/Local Level***
Nuclear Facilities	Emergency Operations Centers	Fire Stations
Government Facilities	Communications Facilities	Police Stations
Large Hospitals	Medium Hospitals	Small Hospitals
High Vulnerability Dams	Intermediate Vulnerability Dams	Low Vulnerability Dams
Military Facilities	Electric Power Facilities	Waste Water Treatment Plants
	Natural Gas Facilities	Potable Water Facilities

The critical facilities exposure category uses the data obtained from the FEMA Hazus-MH Database (FEMA, 2003) and the North Carolina Center for Geographic and Information Analysis (CGIA). Critical facilities data collected from the Hazus-MH database and from CGIA was aggregated to the county FIPS code level for the scoring application process of this risk assessment. The dams, municipal water treatment plants and military facilities indicators were obtained from CGIA. The rest of the indicators were obtained from Hazus-MH. The Hazus-MH indicators were taken directly from the assigned HAZUS label classifications before they were aggregated. The Hazus-MH codes are listed and further described in the Hazus-MH Technical Manual, Chapter 3: Inventory Data, Tables 3-1, 3-15, 3-17, 3-25, 3-28, 3-29, 3-30 (FEMA, 2002a). Hazus-MH data was used where available or when it provided the best available statewide coverage. Several indicators were not populated within the Hazus-MH database at the time of this risk assessment, such as military institutions and municipal water treatment plants. It was in those cases that the CGIA datasets were used to provide the best available data. The CGIA dams included a classification by high, intermediate, and low vulnerability (please see Table 2.2.1.1.B: Dam Hazard Classifications), which was found to be more useful in the sub-category classification. Thus, the CGIA dam dataset was used instead of the Hazus-MH dam facilities for this particular indicator.

3.4.1.5 Category 5 - Transportation Facilities Exposure

The count of transportation facilities was selected as an indicator of exposure in order to quantify the total number of transportation facilities that could be exposed to natural hazards occurring in each county. Higher numbers of these facilities in a county correspond to higher levels of transportation exposure. Aggregation of these indicators is the best measure of total structural exposure for the state based on available data.

The transportation facilities exposure indicators include the count of facilities for the following: airports, bus stations, highway bridges, highway tunnels, ports and railroad stations. The transportation facilities exposure category uses data obtained from the FEMA Hazus-MH Database (FEMA, 2003). Transportation data collected from the Hazus-MH database was aggregated to the county FIPS code level for the scoring application process of this risk assessment. The transportation classes were taken directly from the assigned Hazus label classifications before they were aggregated for the scoring purposes of this risk assessment. The Hazus-MH codes, as well as their corresponding standard industrial codes, are listed and further described in the Hazus-MH Technical Manual, Chapter 3: Inventory Data, Tables 3-18, 3-19, 3-21, 3-22, and 3-24 (FEMA, 2002a). Hazus-MH data on ferry transportation systems and light rail stations were not populated in the dataset for North Carolina at the time of this risk assessment.

3.4.1.6 Category 6 - Environmental Exposure

The count of environmentally hazardous facilities was selected as an indicator of exposure in order to quantify the total number of facilities per environmental hazard type that could be exposed to natural hazards occurring in each county. These facilities were chosen because of their potential detrimental effect on environmental quality if they were to be damaged during a natural hazard event. Higher numbers of these facilities in a county correspond to higher levels of environmental exposure. Aggregation of these indicators is the best measure of total structural exposure for the state based on available data.

The environmental exposure indicators include the count of structures for the following facility types: Hazmat sites, major NPDES dischargers, and registered animal operations. The registered animal operations indicator includes the swine, horse, poultry, and cattle operations of North Carolina.

The environmental exposure category uses data obtained from the FEMA Hazus-MH Database (FEMA, 2003) and the North Carolina CGIA. Environmental data collected from each database was aggregated to the county FIPS code level for the scoring application process of this risk assessment. The Hazmat site data was taken directly from the assigned Hazus label classification. The Hazus-MH coding for Hazmat sites is listed and further described in the Hazus-MH Technical Manual, Chapter 3: Inventory Data, Section 3.8 (FEMA, 2002a). The major NPDES dischargers and registered animal operations data was obtained from CGIA (NCCGIA).

3.4.2 Exposure scoring procedure

After the exposures were identified, they were processed and aggregated into a single table that was based on county census FIPS code. Once in a single Arc INFO file, it was then possible to create a scoring system to assess total state vulnerability. The exposure score is different from the hazard score in that the hazard score included the product of four categories (scope, frequency, intensity, and destructive potential), but the exposure score uses just the range of values available in each dataset. The scores are applied to equal interval classes that can be determined from the raw data and did not require expert input.

Exposure scores were generated from these raw numbers of each indicator per county and applied to a scale of zero to five. The ranges of values used for each indicator score application are shown in Appendix E. The process of assigning the scores of 0 – 5 for each indicator involved the following steps:

- Identification of the minimum and maximum value for each indicator.
- Determination of the differential between the maximum and minimum value for the purposes of total range identification.
    - Total range of values that can be scored = Max value – Min value
- Determination of the ranges in each scoring class for 5 classes.
    - Class Range = Total range of values / 5
    - Minimum value + Class Range = Class 1
    - Class 1 + Class Range = Class 2
    - Class 2 + Class Range = Class 3
    - Class 3 + Class Range = Class 4
    - Class 4 + Class Range = Class 5
- Application of score from 1 – 5 to each class
    - Class 1 = 1 or 5
    - Class 2 = 2 or 4
    - Class 3 = 3
    - Class 4 = 4 or 2
    - Class 5 = 5 or 1

In summary, the minimum value for each indicator was the starting point of five equal interval classes. The same value ("class range") was added five times in succession to the minimum value to create the unique classes for each indicator. After the classes were determined, a score of 1 – 5 was applied, according to the intended influence of the indicator. For example, as the classes of population increased in value, the population exposure increased, and a higher score was applied. However, it was also the case that some types of exposure decreased with an increase in class value. These inversely related indicators received decreasing scores with an increase in value. This was the case for the following indicators: In some cases, the minimum value was zero. In those instances, a "Class 0" was created where all values of zero were assigned a score of 0.

The above procedure of class definition was easily accomplished in Microsoft Excel, yet the assigned scores still needed to be applied to each county in the aggregated indicator database (the single table described at the beginning of this section). This was done in an Arc INFO workstation using a short series of TABLES commands. The ranges were entered into a simple script that selects each indicator in turn and based on the range of values identified in the script according to the classes, assigns a score as determined in the scoring process. This script allows for automation of the scoring application process to take place; although the same process can be done manually in ArcGIS using the select by attribute and field calculator functions. Complete copies of the scripts used for this process are included in Appendix F. The end result of the calculations is a score for each county for each indicator.

Each of the six categories has a different number of indicators associated with it (*Table 6*). In order to create a total score for each of the six categories, the indicator scores were summed and then normalized by the number of indicators in each category:

Total category score = (Σ indicator scores) / # of indicators

For example, the transportation category score for each county was the sum of the scores for airports, bus stations, highway bridges, highway tunnels, ports, and railroad stations divided by six. The sum of the indicators alone would result in a score ranging from 0 – 30, which would be difficult to compare to other categories that have different numbers of indicators. For example, the structures category has ten indicators, which results in a range of 0 – 100 if just the sum of the indicator scores were used, and could not be compared to the transportation exposure score. Thus, it was necessary to divide each of the aggregated indicator scores by the number of indicators to normalize the exposure category scores for comparison.

There were two exceptions to this total category score formula. The first is the population category score. The population category only has one indicator, thus the sum of the indicators was not possible and dividing by the number of indicators was unnecessary. The second exception is the critical facilities category. The critical facilities total category score involved a few extra steps due to the three applied subcategories of local, regional and state level exposure (*Table 7*). First, the scores for each indicator were determined as described. Then, the total category score was broken down by sub-category and calculated, where the indicators in each sub-category were summed and divided by the number of indicators in each sub-category. This resulted in a total score for each sub-category. The total sub-category score was then multiplied by a "weighted factor" to give more weight to the state level exposure sub-category than the regional sub-category, and so forth. The weighted factor values are as follows:

- State level critical facilities exposure sub-category = 1.25
- Regional level critical facilities exposure sub-category = 1.15
- Local/County level critical facilities exposure sub-category = 1.05

The weighted factors were selected to accomplish a separation between the sub-categories and yet not create an unworkable range of values when aggregated with the other exposure categories for the total exposure score. In addition, assigning these values allowed for a comparison of the relative impacts of exposure. The formulas for each sub-category in their entirety are as follows:

Total state level exposure score = (Σ State level indicator scores/ 5) * 1.25
Total regional level exposure score = (Σ Regional level indicator scores/6) * 1.15
Total local level exposure score = (Σ Local level indicator scores/ 6) * 1.05

Once all of the sub-category scores for critical facilities exposure were calculated, the total critical facilities score was determined by simply adding the sub-category scores together and dividing by three:

Total critical facilities exposure score = (State + Regional + Local Scores / 3)

At the end of this process, each of the exposure categories then had a total score for each county. The population, economic activity, structures, transportation and environmental exposure categories each had a resulting score on a scale of 0 – 5 for each county. The total critical facilities score for each county was within a range of 0 – 5.75 as a result of the weighted factors. Each category (and sub-category as in the case of critical facilities) resulted in its own individual map of exposure at the county level. All of the maps can be found in *Section 3*: *Exposure Descriptions and Scores* of the official risk assessment document. An example of the structural category map is shown in *Figure 5*.

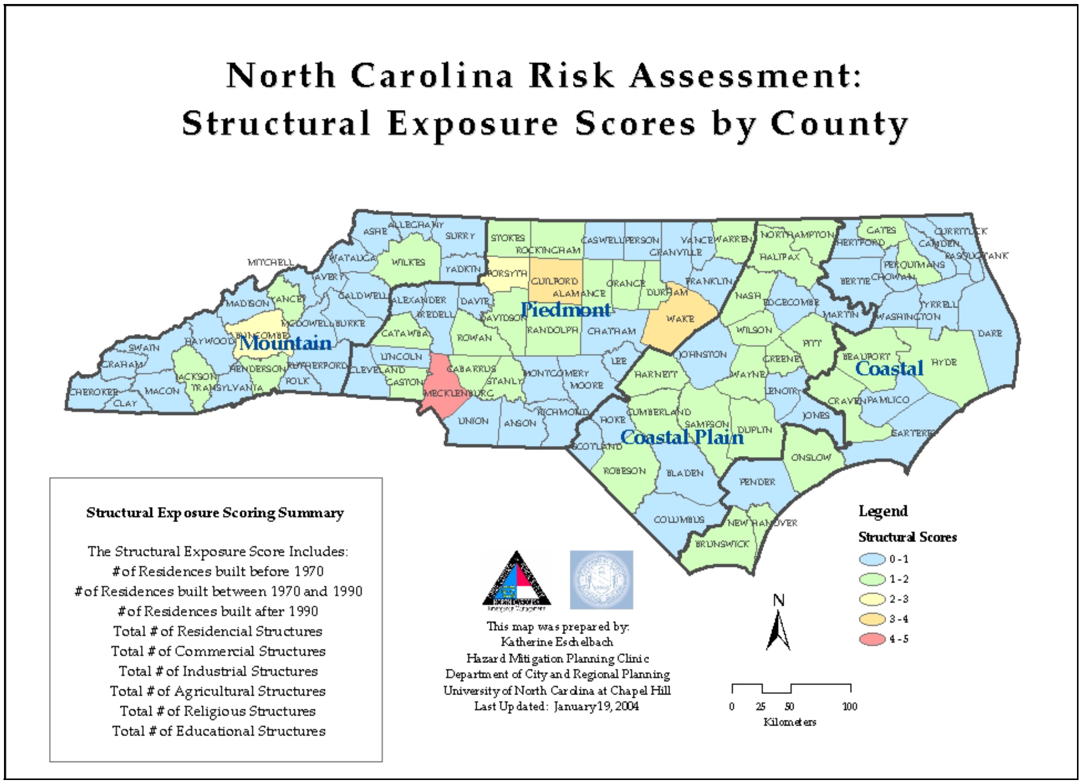


Figure 5: Example Exposure Score Category Map

The higher scores reflect a higher exposure according to the values of indicators in a county as compared to other counties in the state. The scores of exposure vulnerability can be used to identify counties of the state that are most vulnerable to damage from any natural hazard. The exposure scores can also be combined with the hazard scores to determine total vulnerability, which allows for identification of the counties that are most vulnerable to damage associated with each hazard.

3.4.3 Combined exposure scoring procedure

Total exposure vulnerability is the sum of the exposure category scores for each county. The scores represent the relative vulnerability of each county in North Carolina in terms of its exposure to natural hazards. Scores aggregated to this level provide a broad understanding of exposure across North Carolina. The formula to calculate the total exposure score is as follows:

Total exposure score = Σ Exposure category scores

The resulting total exposure composite score map is shown below in *Figure 6*:

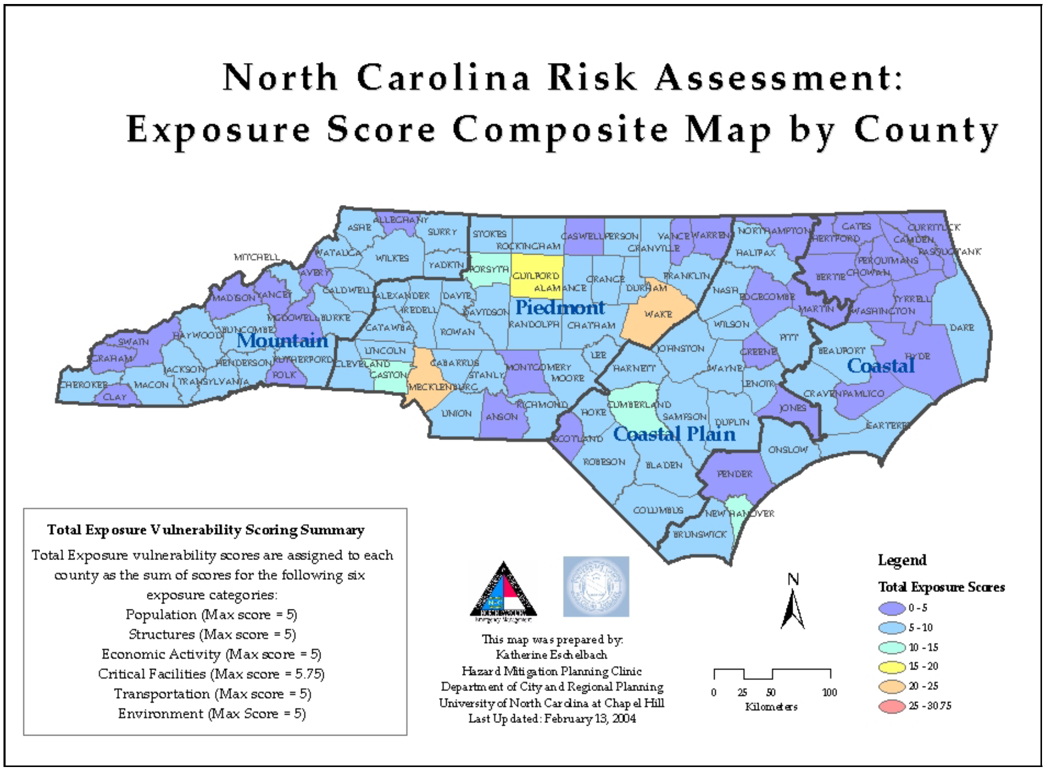


Figure 6: Total Exposure Score Composite Map

The total exposure score is then used as a multiplier of the total hazard score to reach a determination of total vulnerability per county. The process of determining the total vulnerability score is discussed in Section 3.5.

SUMMARY OF EXPOSURE SCORE PROCEDURE:

- Gather all available indicator data and group into exposure categories
- Format all indicators such that each occurrence is identified by Census FIPS code at the county 5-digit level
- Determine the range of values for each indicator (min and max values)
- Determine five equal interval classes within the range for each indicator
  - See Appendix E for all indicator classes
- Apply scores of 0 – 5 to the classes for each indicator
  - See Appendix F for all scripts
- Exposure category score = (Σ indicator scores per county)/(# of indicators)
- Total exposure score = Σ of all exposure category scores
  - See Appendix G for all exposure scores by county
- Scores are entered into a GIS system and mapped for each exposure category and all exposure categories as a composite
  - See Appendix I for a description of GIS processing steps

3.5 Total Vulnerability Scores

The total vulnerability to the counties of North Carolina is the product of the total hazard score (Section 3.3) and the total exposure score (Section 3.4):

Total Vulnerability = Total Hazard Score x Total Exposure Score

The total vulnerability scores are the true indicators of vulnerability for the state because they take into account both the impact of all hazards and the number of people, employees, structures and facilities that could be affected in those areas. The total vulnerability map (with the exclusion of earthquake and flood hazard scores) is shown below in *Figure 7*.

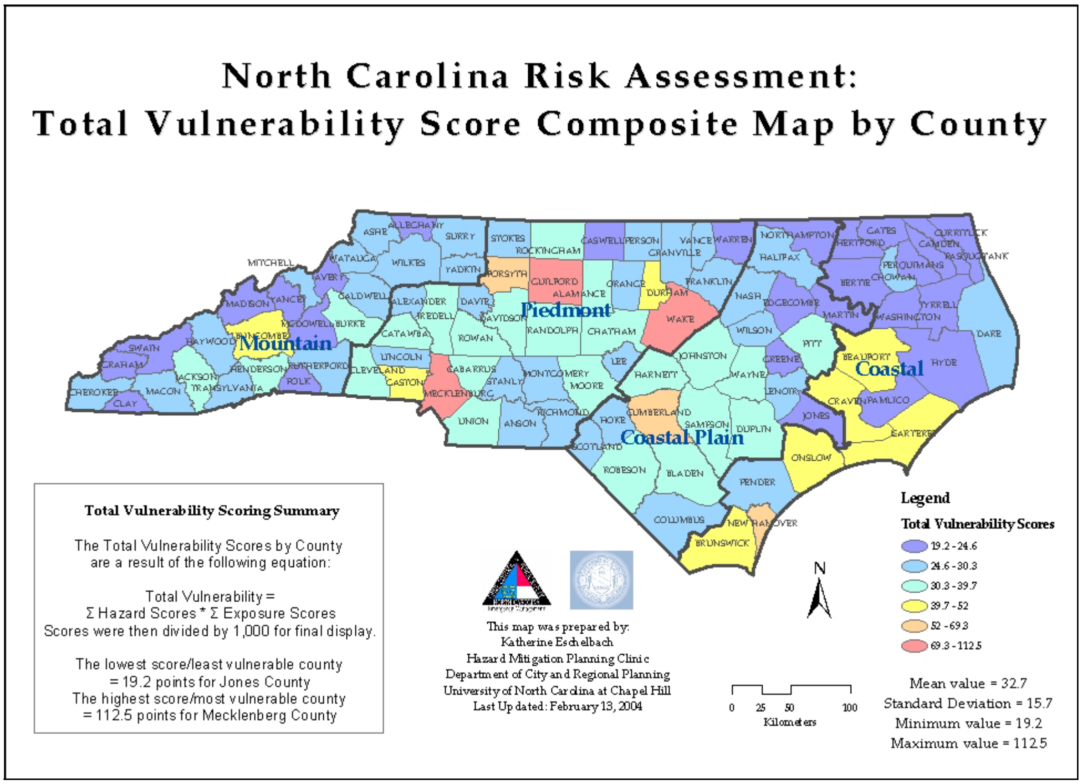


Figure 7: Total Vulnerability Score Composite Map

The scores for total vulnerability can also be manipulated several ways. Each of the six exposure categories can be multiplied in turn by the total hazard score to indicate the total vulnerability to populations, or the total vulnerability to economic activity, etc. For example, the total vulnerability to the population exposure category was calculated according to the following formula:

Population vulnerability = Total Hazard Score * Population Exposure Score

The resulting map is shown below in *Figure 8*. The total economic activity vulnerability, total structural vulnerability, total critical facility vulnerability, total transportation vulnerability, and total environmental vulnerability can be calculated in the same way. The critical facilities category can also be broken down to sub-category to determine the total critical facilities vulnerability at the state, regional, or local levels. All of these maps can be found in the official risk assessment with further discussion about the results in *Section 4.1: Exposure Vulnerability*.

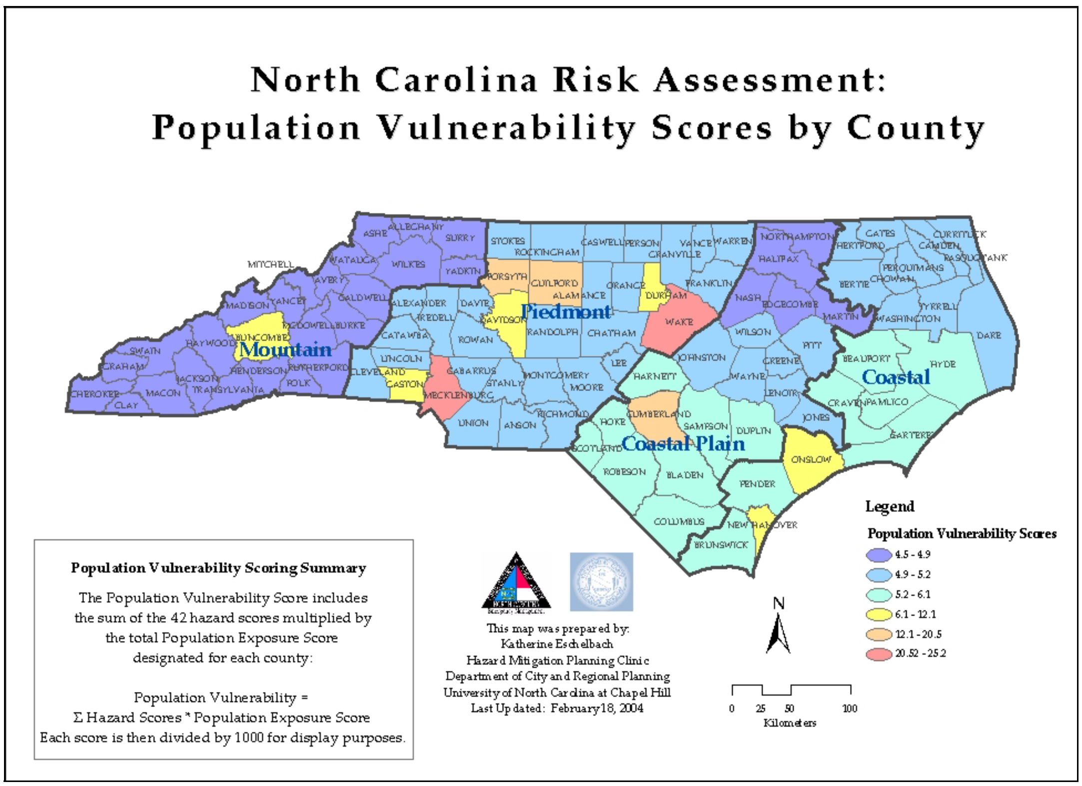


Figure 8: Example Exposure Category Vulnerability Map

Each of the 9 hazard group scores can also be multiplied by the total exposure score to indicate the total vulnerability to flood hazards, etc. For example, the total vulnerability of the state of North Carolina to Wildfire can be calculated for each county using the following formula:

Total Wildfire Vulnerability = Total Exposure Score x Wildfire Score

The resulting map is shown below in *Figure 9*.

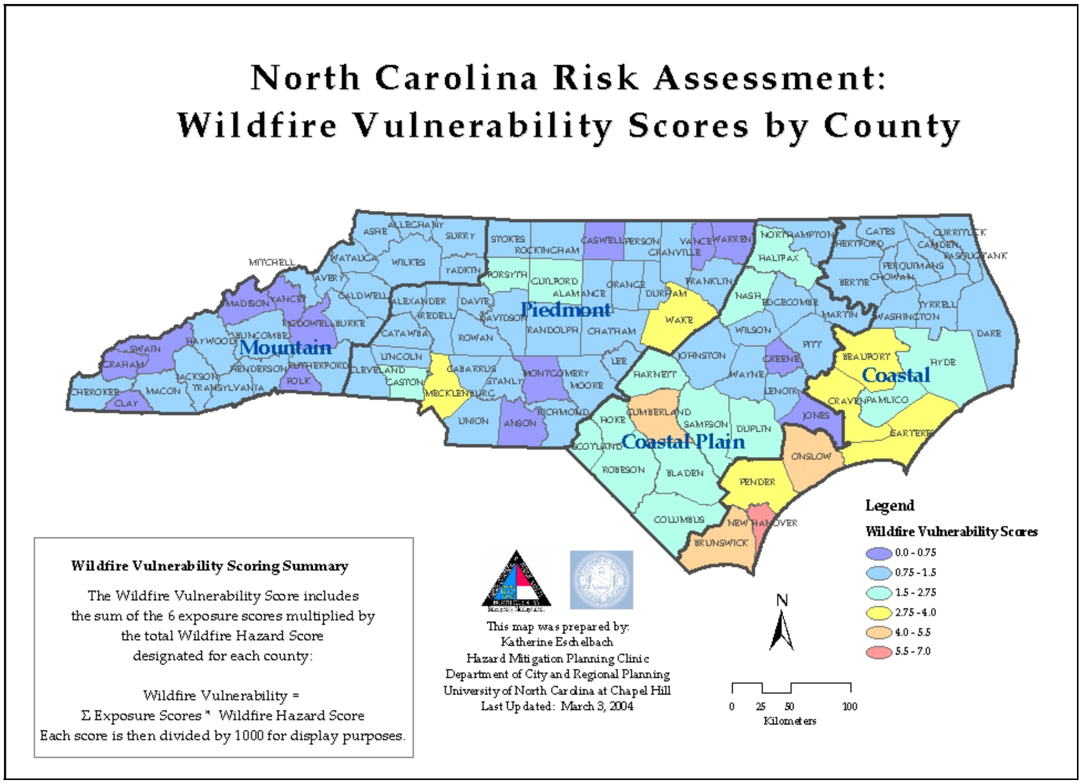


Figure 9: Example Hazard Group Vulnerability Map

This formula can similarly be used to calculate the total hazard vulnerability for each of other the greater and lesser hazard groups, or for each individual hazard. All of the hazard group vulnerability maps are shown and results discussed in *Section 4.2: Hazard Vulnerability* of the official risk assessment document.

SUMMARY OF VULNERABILITY SCORE PROCEDURES:

- Total Vulnerability = Total Hazard Score x Total Exposure Score
- Other possible variations include:
  - Total Hurricane Vulnerability =
    Hurricane individual hazard score x Total Exposure score
    - Can be calculated for each individual hazard
  - Total Coastal Hazards Group Vulnerability =
    Coastal Hazards Group score x total exposure score
    - Can be calculated for each hazard group
  - Total Transportation Vulnerability = Total hazard score x Transportation category score
    - Can be calculated for each exposure category
- Scores are entered into a GIS system and mapped for each type of vulnerability and as a composite
  - See Appendix I for a description of GIS processing steps

4 *DISCUSSION OF METHODS AND RESULTS*

This methodology was successful in assessing the natural hazard vulnerability of North Carolina. The methods described above achieved a quantitative assessment at the county level of the state's identified hazards and exposures. The results not only identify the most vulnerable counties of the state, but also show the spatial relationships among the vulnerable counties and were actively used in the policy formulation process for the state hazard mitigation plan.

The hazard matrix as a whole provided the terms to talk about the similarities and differences between the most important aspects of the hazards as they affect the state. The intensity and destructive potential variables not only allow a comparison to impacts in other states, but also among other natural hazards that affect North Carolina. The natural hazard regions at which level the hazard experts were asked to apply the hazard scores for scope, frequency, intensity, and destructive potential was also successful. Most of the natural hazards fit reasonably within these designated regions when making the score assignments. The hazard experts were pleased with the geographic boundaries because of the flexibility it provided. This flexibility was demonstrated by the ease of score application due to the balance experts could achieve between being too general and too specific about the scope of the hazards.

The geographic units used in this assessment were vital to its success. As mentioned in the introduction, the model assessment for the North Carolina methodology was the risk assessment methodology designed for Rhode Island (Odeh, 2002). The Rhode Island assessment had similar formulas for total vulnerability, but a large difference between the two studies is the scale at which they are performed. It was necessary from the beginning to make adjustments for the North Carolina assessment due to the differences in scale between the two states. The methods applied in North Carolina used a county level scale, versus a tract level scale employed in the Rhode Island assessment. Using the tract level in Rhode Island was helpful due to the small area of the state. Yet, in a state as large as North Carolina, the county level was not only more appropriate for analysis and spatial presentation of the results, but also the smallest scale at which all of the data to be used in the assessment was widely available.

Data availability is always a challenge in spatial analysis. There are many other possible variables that could have been included in the assessment, but were simply not available statewide. This is especially true for the exposure indicators. The use of the HAZUS database, however, was an advantage in having the capability to complete a comprehensive assessment. The availability of data on the hazard side of the vulnerability equation, however, was only limited by the knowledge of the experts that were willing to volunteer their time to the assessment. By incorporating the use of expert opinion, a large number of hazards were able to be identified and evaluated in this assessment, which is a valuable exercise for a state of such varying topography and climate ranges. There are an inherently large number of hazards to assess in North Carolina because of the wide coverage of mountains to the coast, but the methodology allows for all of these hazards to be quantitatively addressed.

The total vulnerability results do contain some bias towards the most populated areas of the state. This is due to the correlation between large numbers of people and large numbers of structures, critical facilities, etc. It is intuitive that the counties that have the most populated areas will in turn have the higher total exposure scores. The way in which the exposure scores were assigned (Appendix E), the highest amounts of population and economic activity and highest number of structures, critical facilities, transportation facilities and environmental exposures were given the highest scores. However, in the total vulnerability maps by hazard group, the higher scoring counties were not always the counties with the highest hazard scores. The bias of the exposure scores could lead to the conclusion that a hazard needs to be targeted in some areas where there is not as much of a hazard as there may be in less populated areas. This is not a downfall of the methodology, however, because it was the goal of this assessment to identify the areas that were most vulnerable to hazards if that particular hazard were to strike that area. The most vulnerable areas of the state were identified as those that had the largest amount of human activity to be disrupted, thus this methodology achieved its goal. If, on the other hand, it was a goal of the assessment to uncover the most vulnerable areas of the state with the least capability to adjust and recover from the hazard, the scoring assignments could easily be reversed or adjusted to accommodate those goals.

The aggregation of hazard groups also provides a substantial bias to the vulnerability results. The individual hazards within the groups are different enough in their total scores such that when they are normalized, an averaging effect takes place and some of the higher and lower vulnerability areas may be lost. The same effect is inherent to the exposure data as well for each category. It is always advised in using this methodology to keep the individual hazard scores and maps as a reference to avoid the improper interpretation of the scores due to these averaging effects.

5 SUGGESTIONS FOR FUTURE USE

This methodology was designed such that future users will have the flexibility to make adjustments and achieve their risk assessment goals. The formulas and geographic units were adjusted from the Rhode Island risk assessment (Odeh, 2002) to fit the larger scale of the state of North Carolina, but can also be applied without adjustment at smaller scales. The counties and municipalities within North Carolina can take the results of the state wide risk assessment and fine tune them for their jurisdiction using the same formulas, only with their own more detailed data. Adjustments can easily be made to the database used in this assessment as the data will be made available on CD and on the internet in future publications of this document. (A listing of field names for this database for ease of interpretation of the data is provided in Appendix H.) The county or municipality may use smaller units of analysis, such as the census block or census tract that was used in the Rhode Island assessment, but the changes in the formulas made for the North Carolina assessment will still be applicable to those smaller units. This can be advantageous to the local jurisdictions in having a streamlined, consistent methodology to follow when meeting their requirements for state and FEMA approval of their hazard mitigation plans.

The use of the methodology at smaller scales will reciprocally benefit the state. The state of North Carolina will (as will all states) be required in the next update of the state hazard mitigation plan to incorporate the risk assessment information contained in the local mitigation plans. This is specified in 44 CFR 201.4(c)(2)(ii). One way in which to accomplish this requirement is to incorporate the data gathered by the risk assessments of the local jurisdictions following this methodology, or other standardized local methodologies, such as the National Oceanic and Atmospheric Administration's Community Vulnerability Assessment Tool (Flax et al., 2002). This information will enable the state to have access to the most recent and highly detailed data possible at the time of the state hazard mitigation plan update. This data could be aggregated again to the county level for the entire state, or be used to create an intermediate level of planning at the regional scale. The more detailed data will be difficult to display and interpret at the state level, but the state plan could be broken up by the regions defined in this methodology, by river basin, or by other natural features that can allow more specific policies to be formulated for the areas that are vulnerable to each hazard.

6 ACKNOWLEDGEMENTS

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8 APPENDIX A: RELEVANT CFR AND FEMA REGION IV REQUIREMENTS

Identifying Hazards (44 CFR 201.4(c)(2)(i)):
44 CFR 201.4 (c): "Plan content. To be effective the plan must include the following elements:

(2) Risk assessments that provide the factual basis for activities proposed in the strategy portion of the mitigation plan. Statewide risk assessments must characterize and analyze natural hazards and risks to provide a statewide overview. This overview will allow the State to compare potential losses throughout the State and to determine their priorities for implementing mitigation measures under the strategy, and to prioritize jurisdictions for receiving technical and financial support in developing more detailed local risk and vulnerability support in developing more detailed local risk and vulnerability assessments. The risk assessment shall include the following:

(i) An overview of the type and location of all natural hazards that can affect the State, including information on previous occurrences of hazard events, as well as the probability of future hazard events, using maps where appropriate"

FEMA Region IV Requirements (FEMA, 2002b):

- "The plan must contain an overview of the type and location of all natural hazards that affect the state"
  - Minimum hazards: Earthquakes, Floods, Tsunamis, Volcanoes, Landslides, Hurricanes and Coastal Storms, Severe Storms/Tornadoes; Wildfires, Dam Failure, Drought/Heat Wave, and Winter Storms/Freezes
- "The overview must document how the hazards were identified or why they were excluded from the State's hazard analysis"

Profiling Hazard Events (44 CFR 201.4(c)(2)(i)): see above
FEMA Region IV Requirements (FEMA, 2002b):

- "The Plan must include an overview of each hazard identified as affecting the State."
  - The overview must include the following for each hazard:
    - information on previous occurrences – including geographic location of event and intensity of impact
    - projection of future occurrences – including geographic location of event and intensity of impact

- maps that identify the areas previously affected by each hazard

Assessing Vulnerability of State Facilities (44 CFR 201.4(c)(2)(ii))

44 CFR 201.4 (c): see above

(2): see above

(ii): "An overview and analysis of the State's vulnerability to the hazards described in this paragraph (c)(2), based on estimates provided in local risk assessments as well as the State risk assessment. The State shall describe vulnerability in terms of the jurisdictions most threatened by the identified hazards, and most vulnerable to damage and loss associated with hazard events. State owned critical or operated facilities located in the identified hazard areas shall also be addressed"

FEMA Region IV Requirements (FEMA, 2002b):

- Address location of state owned critical or operated facilities in each hazard area
    - Inventory should include: their uses, approximate sizes, types, values, and rationale for designation as a critical facility
    - May also address infrastructure owned by the state

Assessing Vulnerability by Jurisdiction (44 CFR 201.4(c)(2)(ii))

(44 CFR 201.4(c)(2)(ii)): see above

FEMA Region IV Requirements (FEMA, 2002b):

- Overview and analysis of the vulnerability of each identified hazard
    - The vulnerability assessment should be based on the hazard risk assessment
    - Should be based on estimates provided in local risk assessments where possible
- Identify and describe the jurisdictions most threatened by each hazard
- Identify and describe the jurisdictions most vulnerable to damage and loss associated with each hazard

9 *APPENDIX B: HAZARD MATRIX*

(it is advised that the matrix be concatenated into one Excel spreadsheet and printed on a large format printer)

HAZARD		**SCOPE (GEOGRAPHIC EXTENT)**											
		State	**Regional**										
			Mountain		**Piedmont**			**Coast**					
								Coastal Plain			**Coastal**		
			1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**6**	**7**	**8**
Severe Winter Weather		5	5	5	5	5	5	5	5	5	5	5	5
	Freezing Rain (ice storm & sleet)	5	5	5	5	5	5	5	5	5	5	5	5
	Snowstorms	5	5	5	5	5	5	5	5	5	5	5	5
	Blizzards	5	5	5	5	5	5	5	5	5	5	5	5
	Wind Chill	5	5	5	5	5	5	5	5	5	5	5	5
Extreme Cold		5	5	5	5	5	5	5	5	5	5	5	5
Severe Thunderstorm		5	5	5	5	5	5	5	5	5	5	5	5
	Hailstorms	5	5	5	5	5	5	5	5	5	5	5	5
	Torrential Rain (Flash Flood)	5	5	5	5	5	5	5	5	5	5	5	5
	Thunderstorm Wind	5	5	5	5	5	5	5	5	5	5	5	5
	Lightning	5	5	5	5	5	5	5	5	5	5	5	5
Tornadoes		5	5	5	5	5	5	5	5	5	5	5	5
	Waterspout		0	0	0	0	0	0	0	0	5	5	5
High Wind		5	5	5	5	5	5	5	5	5	5	5	5
Hurricanes/Tropical Storm		5	5	5	5	5	5	5	5	5	5	5	5
	Storm Surge		0	0	0	0	0	0	0	0	5	5	5

	High Wind	5	5	5	5	5	5	5	5	5	5	5	5
	Torrential Rain	5	5	5	5	5	5	5	5	5	5	5	5
	Tornadoes	5	5	5	5	5	5	5	5	5	5	5	5
Nor-easters		5	5	5	5	5	5	5	5	5	5	5	5
	High Wind		0	0	0	0	0	5	5	5	5	5	5
	Storm Surge		0	0	0	0	0	0	0	0	5	5	5
	Severe Winter Weather	5	5	5	5	5	5	5	5	5	5	5	5
Drought		5	5	5	5	5	5	5	5	5	5	5	5
	Hydrologic	5	5	5	5	5	5	5	5	5	5	5	5
	Agricultural	5	5	5	5	5	5	5	5	5	5	5	5
Heat Waves			0	0	5	5	5	5	5	5	5	5	5
Fog		5	5	5	5	5	5	5	5	5	5	5	5
Rip Currents			0	0	0	0	0	0	0	0	5	5	5
Avalanches		0	0	0	0	0	0	0	0	0	0	0	0
Debris Flow (Landslides)			5	5	5	5	5	0	0	0	0	0	0
Volcanoes		0	0	0	0	0	0	0	0	0	0	0	0
Expansive Soils			5	5	5	5	5	5	5	5	0	0	0
Acidic Soils		5	5	5	5	5	5	5	5	5	5	5	5
Subsidence			0	0	5	5	5	5	5	5	5	5	5
Mine Collapse			5	5	5	5	5	0	0	0	0	0	0
Dam Failure		5	5	5	5	5	5	5	5	5	5	5	5
Sinkholes			5	0	0	0	0	5	5	0	5	5	0
Coastal Erosion		0	0	0	0	0	0	0	0	0	5	5	5
Geochemical -related		5	5	5	5	5	5	5	5	5	5	5	5
Tsunami		0	0	0	0	0	0	0	0	0	5	5	5
Wildfire		5	5	5	5	5	5	5	5	5	5	5	5

	FREQUENCY OF OCCURRENCE											
	State	**Regional**										
		Mountain		**Piedmont**			**Coast**					
							Coastal Plain			**Coastal**		
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**6**	**7**	**8**
SWW		4	4	4	4	4	4	4	4	3	3	3
FR		4	4	4	4	4	4	4	4	3	3	3
S		4	4	4	4	4	4	4	4	3	3	3
B		3	3	2	2	2	2	2	2	1	1	1
WC		3	3	3	3	3	2	2	2	2	2	2
EC	1	1	1	1	1	1	1	1	1	1	1	1
ST	5	5	5	5	5	5	5	5	5	5	5	5
H	5	5	5	5	5	5	5	5	5	5	5	5
TR	4	4	4	4	4	4	4	4	4	4	4	4
TW	5	5	5	5	5	5	5	5	5	5	5	5
L	5	5	5	5	5	5	5	5	5	5	5	5
T		4	4	5	5	5	5	5	5	5	5	5
W										5	5	5
HW		4	4	3	3	3	3	3	3	4	4	4
H	3	3	3	3	3	3	3	3	3	3	3	3
SS										3	3	3
HW		2	2	3	3	3	3	3	3	3	3	3
TR	3	3	3	3	3	3	3	3	3	3	3	3
T		2	2	3	3	3	3	3	3	3	3	3

NE		3	3	3	3	3	4	4	4	5	5	5
HW							4	4	4	5	5	5
SS										4	5	5
SWW	3	3	3	3	3	3	3	3	3	3	3	3
D	3	3	3	3	3	3	3	3	3	3	3	3
HY	3	3	3	3	3	3	3	3	3	3	3	3
AG	3	3	3	3	3	3	3	3	3	3	3	3
HEAT				4	4	4	4	4	4	4	4	4
F	5	5	5	5	5	5	5	5	5	5	5	5
RC										5	5	5
A												
DFL		5	5	3	3	3						
V												
ES		4	4	5	5	5	4	4	4			
AS		5	4	4	4	4	5	5	4	5	5	4
S				5	5	5	5	5	5	5	5	5
MC		3	4	5	5	5						
DF		5	4	5	4	5	5	4	3	4	4	3
SH		3					5	4		5	4	
CE										5	5	5
VR		4	4	5	5	5	3	3	3	3	3	3
TS										1	1	1
W	5	5	5	5	5	5	5	5	5	5	5	5

	INTENSITY											
	State	**Regional**										
		Mountain		**Piedmont**			**Coast**					
								Coastal Plain		**Coastal**		
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**6**	**7**	**8**
SWW		3	3	4	4	3	2	3	3	1	2	2
FR		2	3	4	4	3	2	3	3	1	2	2
S		3	3	3	3	3	2	2	2	1	1	1
B	1	1	1	1	1	1	1	1	1	1	1	1
WC	1	1	1	1	1	1	1	1	1	1	1	1
EC	1	1	1	1	1	1	1	1	1	1	1	1
ST	4	4	4	4	4	4	4	4	4	4	4	4
H	3	3	3	3	3	3	3	3	3	3	3	3
TR	4	4	4	4	4	4	4	4	4	4	4	4
TW	3	3	3	3	3	3	3	3	3	3	3	3
L		3	3	3	3	3	4	4	3	4	4	3
T	1	1	1	1	1	1	1	1	1	1	1	1
W										1	1	1
HW		2	2	1	1	1	1	1	1	2	2	2
H		5	5	5	5	5	5	5	5	5	5	5
SS										4	4	4
HW		1	1	1	1	1	2	2	2	2	2	2

TR	5	5	5	5	5	5	5	5	5	5	5	5
T	1	1	1	1	1	1	1	1	1	1	1	1
NE		1	1	2	2	2	3	3	3	3	3	3
HW							2	2	2	3	3	3
SS										2	3	3
SWW		1	1	2	2	2	3	3	3	2	2	2
D	4	4	4	4	4	4	4	4	4	4	4	4
HY	3	3	3	3	3	3	3	3	3	3	3	3
AG	4	4	4	4	4	4	4	4	4	4	4	4
HEAT				3	3	3	4	4	4	4	4	4
F	3	3	3	3	3	3	3	3	3	3	3	3
RC										4	4	4
A												
DFL		4	4	2	2	2						
V												
ES		3	3	4	4	4	3	3	3			
AS		4	4	3	3	3	5	5	1	1	1	1
S				3	3	3	5	5	3	5	5	3
MC		3	3	4	4	4						
DF		2	2	3	2	4	4	2	1	2	2	2
SH		2					5	4		5	4	
CE										5	5	5
VR	3	3	3	3	3	3	3	3	3	3	3	3
TS										5	5	5
W		3	4	2	2	2	4	2	3	5	5	5

	DESTRUCTIVE POTENTIAL											
	State	**Regional**										
		Mountain		**Piedmont**			**Coast**					
							Coastal Plain			**Coastal**		
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**6**	**7**	**8**
SWW	4	4	4	4	4	4	4	4	4	4	4	4
FR	4	4	4	4	4	4	4	4	4	4	4	4
S	2	2	2	2	2	2	2	2	2	2	2	2
B	3	3	3	3	3	3	3	3	3	3	3	3
WC	1	1	1	1	1	1	1	1	1	1	1	1
EC	1	1	1	1	1	1	1	1	1	1	1	1
ST		4	4	3	3	3	3	3	3	3	3	3
H	3	3	3	3	3	3	3	3	3	3	3	3
TR		4	4	3	3	3	3	3	3	3	3	3
TW	3	3	3	3	3	3	3	3	3	3	3	3
L	2	2	2	2	2	2	2	2	2	2	2	2
T	4	4	4	4	4	4	4	4	4	4	4	4
W										1	1	1
HW	1	1	1	1	1	1	1	1	1	1	1	1
H	5	5	5	5	5	5	5	5	5	5	5	5
SS										4	4	4
HW		2	2	2	2	2	3	3	3	4	4	4
TR	4	4	4	4	4	4	4	4	4	4	4	4
T	2	2	2	2	2	2	2	2	2	2	2	2

NE		1	1	2	2	2	3	3	3	3	3	3
HW							1	1	1	2	2	2
SS										3	3	3
SWW		1	1	2	2	2	3	3	3	2	2	2
D	4	4	4	4	4	4	4	4	4	4	4	4
HY	4	4	4	4	4	4	4	4	4	4	4	4
AG	4	4	4	4	4	4	4	4	4	4	4	4
HEAT				1	1	1	1	1	1	1	1	1
F	1	1	1	1	1	1	1	1	1	1	1	1
RC										1	1	1
A												
DFL		4	4	2	2	2						
V												
ES		2	2	2	2	2	2	2	2			
AS		3	3	3	3	3	3	3	1	1	1	1
S				2	2	2	2	2	2	2	2	2
MC		2	2	3	3	3						
DF		3	3	3	3	3	2	2	1	1	1	1
SH		2					4	3		4	3	
CE										3	3	3
VR		2	2	2	2	2	2	2	2	1	1	1
TS										5	5	5
W		2	2	3	3	3	4	3	4	5	3	2

	HAZARD SCORE (SxFxIxD)											
	State	Regional										
		Mountain		Piedmont			Coast					
							Coastal Plain			Coastal		
		1	2	3	4	5	6	7	8	6	7	8
SWW	0	240	240	320	320	240	160	240	240	60	120	120
FR	0	160	240	320	320	240	160	240	240	60	120	120
S	0	120	120	120	120	120	80	80	80	30	30	30
B	0	45	45	30	30	30	30	30	30	15	15	15
WC	0	15	15	15	15	15	10	10	10	10	10	10
EC	5	5	5	5	5	5	5	5	5	5	5	5
ST	0	400	400	300	300	300	300	300	300	300	300	300
H	225	225	225	225	225	225	225	225	225	225	225	225
TR	0	320	320	240	240	240	240	240	240	240	240	240
TW	225	225	225	225	225	225	225	225	225	225	225	225
L	0	150	150	150	150	150	200	200	150	200	200	150
T	0	80	80	100	100	100	100	100	100	100	100	100
W	0	0	0	0	0	0	0	0	0	25	25	25
HW	0	40	40	15	15	15	15	15	15	40	40	40
H	0	375	375	375	375	375	375	375	375	375	375	375
SS	0	0	0	0	0	0	0	0	0	240	240	240
HW	0	20	20	30	30	30	90	90	90	120	120	120
TR	300	300	300	300	300	300	300	300	300	300	300	300
T	0	20	20	30	30	30	30	30	30	30	30	30

NE	0	15	15	60	60	60	180	180	180	225	225	225
HW	0	0	0	0	0	0	40	40	40	150	150	150
SS	0	0	0	0	0	0	0	0	0	120	225	225
SWW	0	15	15	60	60	60	135	135	135	60	60	60
D	240	240	240	240	240	240	240	240	240	240	240	240
HY	180	180	180	180	180	180	180	180	180	180	180	180
AG	240	240	240	240	240	240	240	240	240	240	240	240
HEAT	0	0	0	60	60	60	80	80	80	80	80	80
F	75	75	75	75	75	75	75	75	75	75	75	75
RC	0	0	0	0	0	0	0	0	0	100	100	100
	0	0	0	0	0	0	0	0	0	0	0	0
A	0	0	0	0	0	0	0	0	0	0	0	0
DFL	0	400	400	60	60	60	0	0	0	0	0	0
V	0	0	0	0	0	0	0	0	0	0	0	0
ES	0	120	120	200	200	200	120	120	120	0	0	0
AS	0	300	240	180	180	180	375	375	20	25	25	20
S	0	0	0	150	150	150	250	250	150	250	250	150
MC	0	90	120	300	300	300	0	0	0	0	0	0
DF	0	150	120	225	120	300	200	80	15	40	40	30
SH	0	60	0	0	0	0	500	240	0	500	240	0
CE	0	0	0	0	0	0	0	0	0	375	375	375
VR	0	120	120	150	150	150	90	90	90	45	45	45
TS	0	0	0	0	0	0	0	0	0	125	125	125
W	0	150	200	150	150	150	400	150	300	625	375	250

10 APPENDIX C: INDIVIDUAL EXPERT MEETING NOTES

Meteorological Hazard Meeting 7/21/03
NCSU Centennial Campus – State Climate Office
Present: Jeff Orrock, Ryan Boyles, Peter Robinson, Christy Edmonson, Kate Eschelbach

General Notes:

- Historic events are usually detailed at climate zone level, approval of use of climate regions; climate region 6 and 8 need switched
- Each state has a different hazard definition – NC goes by the National Weather Service
- Decided to change several of the hazard subcategories
- Wind should be its own category, but also should be a part of hurricanes, nor'easters and severe winter weather
- Destructive Potential could be local versus county wide versus alert the entire state….
- rip currents overlap between geological and meteorological – coastal geology should look at it especially to see if they agree with or not; is also very localized, only several of the CAMA counties are concerned with it
- tornadoes do happen in the mountains with hurricanes (ex: Hugo and Camille)
- started with the worst event, then went across matrix to set the standard – did hurricanes first
- destructive potential was only really based (to them) on how much could be damaged structure–wise, not on the number of deaths
- intensity as a whole is compared to other hazards across the nation, if NC was average for the US, then it received an intensity score of 3
- concluding remarks by all: felt more comfortable with this matrix than before

Individual Hazard Score Designation Notes:

- Hurricanes – intensity issue with saffir-simpson only including hurricanes from 1-5, not tropical storms, so included tropical storms in the "1" score (check with CLE on this for sure)
    - Storm surge is worse in climate region 6 in association with hurricanes, but hurricane surge is the same as nor'easter surge in 7&8

- Nor'easters – North Carolina doesn't ever get direct effects of them, so for intensity (when compared to others across the nation), a 5 would = Boston/New England, thus they will be the same as a minimal hurricane here in NC (category 1)
- Rip Currents – think it is important to include them so coastal counties are aware of the problem, but don't think that it should get a high score
- Severe Winter Storms – did the components of the category first, then went back to look at overall scoring and defaulted to the higher of the scores below it (or higher if thought that a combo of all components would be worse) – note: need to make sure to look at the state definitions for these hazards!
  - Blizzards – if it occurs, it barely occurs everywhere/barely makes the mark for a blizzard according to its definition (even though it is intense); if happened on the coast it would really cause a problem
  - Wind chill – how often will it be a problem? (it happens a lot, but not at an extreme enough level to make a difference)
  - Destructive potential – freezing rain should be highest no matter where it is across the state
- Extreme Cold – debate about when it is a problem or has been historically a problem - - can't be that important if they don't know much about it! (Peter)
  - Promised to find us a good definition
- Thunderstorms – did components first again, look at state definition
  - Hailstorms – major storm here = golfball sized hail, hard to quantify hail destructive potential because lots of small sized hail = crop damage, where as large hail = property damage
  - Torrential rain – more moisture available than in the rest of the US, can cause true flash floods in mtns, thus higher destructive potential
  - Wind – get lots of it on average
  - Lightening – above average
- Tornadoes – frequency issue b/c they happen on average once every year in each climate division, but not in every county once a year; also have to think about normalizing for unseen tornadoes in lesser populated areas
- Waterspout – most don't do much , are over water, very minor damage

- High wind – highest in coast and in mountains (frequency), just by themselves (aside from hurricanes, etc.), decided it wasn't that bad of a hazard
- Drought – doesn't include coast as much because of sea breeze for both agriculture and hydrologic drought; not concerned with groundwater; intensity for water supply isn't as great – so the intensity score for hydrological drought is lower than agricultural drought
- Heat waves – Peter's expertise!
- Fog – either you have it or you don't, think 3 is fair because it is average across the US

Geological Hazard Meeting #1 7/29/03
North Carolina Dept. of Environment and Natural Resources Archdale Building
Present: Tami Idol, Jim Simons, Kate Eschelbach, Christy Edmonson

General Notes:

- their figures on the Hazard Matrix are conservative, on the safe side, may be overestimating time frame of occurrence)
- Intensity: 3 = average around the country

Hazard Specific Notes:

- Avalanche
  - Separate definition from Debris Flow; avalanche involves snow
- Volcanoes
  - Not present
- Dam Failure
  - Could be internal (pressure) trigger or from a heavy rain event
  - Frequency: Charlotte – so many dams, stressed by increased runoff. Coastal dam failures are tied to hurricanes.
  - Intensity: NC has more dams than any other state, this year it has the highest *hazard dams* = more people are driving across them or living below them, more people are moving in. Dams are being reclassified b/c of more people driving across them.
  - Destructive potential: Dams are the worst. Dams aren't as high along the coast: land is flatter, more spread-out, the dams are made of sand. Destructive potential depends on dam type and size
- Landslides/Debris Flow
  - Caused by road cuts in the coastal plain, but this is not *natural*
  - Intensity: 4 in mountains
  - Destructive potential: 2nd. A landslide is not going to take out a town. Destructive potential is based on property and aerial extent.
- Volcanic Rock
  - This is a chemical problem; causes arsenic in the water (They will get back to us on this one)
  - Frequency: there all of the time, but hear about it every 2 to 4 years b/c only hear about it when it is drilled into
  - Intensity: no hot zones
- Expansive Soils
  - Definition: soils expanding and contracting due to wet/dry conditions

  - Frequency: there all of the time, but don't hear about it all of the time
  - Destructive Potential: a problem if you build on them. Causes cracks in foundations, minor problems
- Acidic Soils
  - Common, but haven't found them in NC, but could. Pyrite, gold mining areas
  - Acidic water causes fish kills
  - Intensity: where they occur, they are bad
  - Destructive Potential: more of an environmental problem. If it sits there it could be hazardous
- Subsidence
- Mines or sinkholes
  - In Triassic region (clays and silts)– problem with house foundations
  - East of 95 – roads need to be stronger
  - Coastal Plain (sedimentary clays) – caused by dewatering; aquifer depletion
  - Frequency: roads and building foundations are a secondary effect
  - Destructive Potential: may be getting worse. Limestone disintegrates from aquifer depletion. Mines are pulling too much water and limestone forms in water, therefore, without water the limestone is collapsing causing subsidence. Wilmington may be having a problem. Gabrielle Cooper
- Mine Collapse
  - Frequency: Currently we are not building on any mines, yet. Region 5 is now a *hot bed*: "oldtimers" have died and current residents don't know where the mines are. I85: old historic gold mines
- Radon
  - Division of Health – good information; Rick and Jeff in GS office
  - Igneous rocks – everywhere but the coast
  - Frequency: better tests now: we are aware of it. Varies with atmospheric pressure
- Sinkholes
  - North / South split through state along the coast. South: limestone, North: sandy
  - Destructive Potential: will be becoming a problem with more people and more pumping.

Wildfire Hazard Meeting 8/13/03
North Carolina Dept. of Environment and Natural Resources Archdale Building
Present: Carl Johnson , Kate Eschelbach

- entire Piedmont is not a big fire concern
- intensity in mountains is higher because of terrain and more rain
- the Sandhills of NC (coastal plain 6) have a lot of drainage, thus the intensity of fires will be higher
- Coastal plain 7, however, isn't as sandy, so wasn't scored as high as coastal plain 6 for intensity
- Coastal plain and coastal 8 – lots of pine plantations have been planted versus farms that used to be the predominant land use, gets lots of precip
- Coastal 6 – has the largest unbroken tracts of timber, thus will give it the highest intensity score
- Coastal 7 – somewhat similar to coastal 6, lost of timber, esp. Hyde and Dare Counties
- Destructive Potential was based on the damage caused by economic loss in the east and destruction of structures in the rest of the state
- The Piedmont has a lot of structures, gave it a higher score
- Coastal Plain 6 – lots of potential there for a lot of damage if a fire hit in the right place
- Coastal 6 = really bad when dry, received high score
- Coastal 7 – around Lake Mattamuskeet there are really strong fires

Coastal Hazards Meeting 9/05/03
NC State University Campus
Present: Marjorie Overton, Kate Eschelbach, Christy Edmonson

- Coastal Erosion was limited in scope to just the three coastal regions
- Has extremely high frequency and intensity, but destructive potential was considered average as compared to other hazards in NC
- Tsunami – there is potential for a large-scale submarine slope failure that will generate a tsunami along the Mid-Atlantic coast, instructed to look up more information on the topic (several publications debating the possibility)
    - Driscoll, N.W. et al., May 2000. Geology, Vol. 28, No. 5, p.407-410.
- Overall, the scope was agreed to include all coastal regions and it was agreed that the frequency should be scored very low. Intensity and Destructive Potential depends on what is researched from the literature.

Geological Hazards Meeting #2 1/21/04
North Carolina Dept. of Environment and Natural Resources Archdale Building
Present: Tami Idol, Jeff Reid, Kate Eschelbach

(A second geological meeting was called to follow up on Radon and Volcanic Rock scores, take a look at all destructive potential scores to double check them, and to seek further advice on the tsunami hazard.)

- It was decided that the radon hazard would be eliminated by itself and instead included with volcanic rock in an overall "geochemical-related" hazards category.
- Geochemical –related hazards are the specialty of Jeff Reid at the Geological Survey, has compiled a website of statewide coverage for many geochemical hazards that were employed and very helpful during the scoring process: (http://www.geology.enr.state.nc.us/NUREgeochem/geochem2.htm)
- The new hazards category includes: arsenic, uranium(including radon), manganese and selenium.
- Acidic soils scores were revised using Jeff's low pH maps – intensity and destructive potential were scored too high to start and were lowered in the coastal regions.
- Tsunami was scored for intensity and destructive – was given the highest score due to information Jeff provided:
    - LaPalma – a crack in the side of this volcano in the Canary Islands could eventually give way and cause a massive landslide that will translate into a wave that will travel across the Atlantic with North Carolina as a prime target; geologists are watching closely, could fall away during the next 100 years and cause an immense tsunami
    - References:
        - http://www.palmod.uni-bremen.de/~akluegel/LaPalmaInfo/lapalma1.htm
        - http://www/rense.com/general13/tidal.htm
        - http://www.cnn.com/2001/TECH/science/08/29/tidal.wave/
    - Gas Hydrates – stored up underneath the continental shelf, could cause earthquakes and generate tsunamis for North Carolina
    - Reference:
        - http://marine.usgs.gov/fact-sheets/gas-hydrates/title.html
- Tami approved of the rest of the destructive potential scores in relation to the rest of the hazards in NC

11 APPENDIX D: HAZARD SCORE BY COUNTY

Hazard Score Sheets by Climate Region

Regions:	Climate Region 1 – Mountain	(17 Counties)
	Climate Region 2 – Mountain	(8 Counties)
	Climate Region 3 – Piedmont	(13 Counties)
	Climate Region 4 – Piedmont	(10 Counties)
	Climate Region 5 – Piedmont	(11 Counties)
	Climate Region 6 – Coastal Plain	(9 Counties)
	Climate Region 6 – Coastal	(4 Counties)
	Climate Region 7 – Coastal Plain	(7 Counties)
	Climate Region 7 – Coastal	(5 Counties)
	Climate Region 8 – Coastal Plain	(5 Counties)
	Climate Region 8 – Coastal	(11 Counties)

Mountain 1: 17 Counties

Cherokee
Clay
Macon
Graham
Swain
Jackson
Haywood
Transylvania
Henderson
Buncombe
Madison
Yancey
Mitchell
McDowell
Polk
Rutherford
Burke

Top 5 Hazard Scores

Debris Flow (Landslide) = 400
Severe Thunderstorm = 400
Hurricane = 375
Acidic Soils = 300
Severe Winter Weather = 240
Drought = 240
Dam Failure = 150
Wildfire = 150

Hazard Scores

Severe Winter Weather = 240
Extreme Cold = 5
Severe Thunderstorm = 400
Tornadoes = 80
High Winds = 40
Hurricane/Tropical Storm = 375
Nor'easters = 15
Drought = 240
Heat Wave = 0
Fog = 75
Rip Currents = 0
Avalanche = 0
Debris Flow (Landslide) = 400
Volcanoes = 0
Expansive Soils = 120
Acidic Soils = 300
Subsidence = 0
Mine Collapse = 90
Dam Failure = 150
Sink Holes = 60
Coastal Erosion = 0
Geochemical-related = 120
Tsunami = 0
Wildfire = 150

Hazard Sub-Scores

Severe Winter Weather
- Freezing Rain = 160
- Snowstorm = 120
- Blizzards = 45
- Wind Chill = 15

Severe Thunderstorm
- Hailstorm = 225
- Torrential Rain = 320
- Thunderstorm Wind = 225
- Lightning = 150

Tornadoes
- Waterspout = 0

Hurricane/Tropical Storm
- Storm Surge = 0
- High Winds = 20
- Torrential Rain = 300
- Tornadoes = 20

Nor'easters
- High Winds = 0
- Storm Surge = 0
- Severe Winter Weather = 15

Drought
- Hydrological = 180
- Agricultural = 240

Mountain 2: 8 Counties
Avery
Caldwell
Watauga
Ashe
Wilkes
Alleghany
Surry
Yadkin

Top 5 Hazard Scores
Debris Flow (Landslide) = 400
Severe Thunderstorm = 400
Hurricane = 375
Severe Winter Weather = 240
Acidic Soils = 240
Drought = 240
Wildfire = 200

Hazard Scores
Severe Winter Weather = 240
Extreme Cold = 5
Severe Thunderstorm = 400
Tornadoes = 80
High Winds = 40
Hurricane/Tropical Storm = 375
Nor'easters = 15
Drought = 240
Heat Wave = 0
Fog = 75
Rip Currents = 0
Avalanche = 0
Debris Flow (Landslide) = 400
Volcanoes = 0
Expansive Soils = 120
Acidic Soils = 240
Subsidence = 0
Mine Collapse = 120
Dam Failure = 120
Sink Holes = 0
Coastal Erosion = 0
Geochemical-related = 120
Tsunami = 0
Wildfire = 200

Hazard Sub-Scores
Severe Winter Weather
- Freezing Rain = 240
- Snowstorm = 120
- Blizzards = 45
- Wind Chill = 15

Severe Thunderstorm
- Hailstorm = 225
- Torrential Rain = 320
- Thunderstorm Wind = 225
- Lightning = 150

Tornadoes
- Waterspout = 0

Hurricane/Tropical Storm
- Storm Surge = 0
- High Winds = 20
- Torrential Rain = 300
- Tornadoes = 20

Nor'easters
- High Winds = 0
- Storm Surge = 0
- Severe Winter Weather = 15

Drought
- Hydrological = 180
- Agricultural = 240

Piedmont 3 : 13 Counties

Stokes
Forsyth
Rockingham
Guilford
Caswell
Alamance
Person
Orange
Durham
Granville
Vance
Warren
Franklin

Top 5 Hazard Scores

Hurricane = 375
Severe Winter Weather = 320
Severe Thunderstorm = 300
Mine Collapse = 300
Drought = 240
Dam Failure = 225

Hazard Scores

Severe Winter Weather = 320
Extreme Cold = 5
Severe Thunderstorm = 300
Tornadoes = 100
High Winds = 15
Hurricane/Tropical Storm = 375
Nor'easters = 60
Drought = 240
Heat Wave = 60
Fog = 75
Rip Currents = 0
Avalanche = 0
Debris Flow (Landslide) = 60
Volcanoes = 0
Expansive Soils = 200
Acidic Soils = 180
Subsidence = 150
Mine Collapse = 300
Dam Failure = 225
Sink Holes = 0
Coastal Erosion = 0
Geochemical-related = 150
Tsunami = 0
Wildfire = 150

Hazard Sub-Scores

Severe Winter Weather
- Freezing Rain = 320
- Snowstorm = 120
- Blizzards = 30
- Wind Chill = 15

Severe Thunderstorm
- Hailstorm = 225
- Torrential Rain = 240
- Thunderstorm Wind = 225
- Lightning = 150

Tornadoes
- Waterspout = 0

Hurricane/Tropical Storm
- Storm Surge = 0
- High Winds = 30
- Torrential Rain = 300
- Tornadoes = 30

Nor'easters
- High Winds = 0
- Storm Surge = 0
- Severe Winter Weather = 60

Drought
- Hydrological = 180
- Agricultural = 240

Piedmont 4 : 10 Counties

Alexander
Catawba
Iredell
Davie
Rowan
Davidson
Randolph
Chatham
Lee
Wake

Top 5 Hazard Scores

Hurricane = 375
Severe Winter Weather = 320
Severe Thunderstorm = 300
Mine Collapse = 300
Drought = 240
Expansive Soils = 200

Hazard Scores

Severe Winter Weather = 320
Extreme Cold = 5
Severe Thunderstorm = 300
Tornadoes = 100
High Winds = 15
Hurricane/Tropical Storm = 375
Nor'easters = 60
Drought = 240
Heat Wave = 60
Fog = 75
Rip Currents = 0
Avalanche = 0
Debris Flow (Landslide) = 60
Volcanoes = 0
Expansive Soils = 200
Acidic Soils = 180
Subsidence = 150
Mine Collapse = 300
Dam Failure = 120
Sink Holes = 0
Coastal Erosion = 0
Geochemical-related = 150
Tsunami = 0
Wildfire = 150

Hazard Sub-Scores

Severe Winter Weather
- Freezing Rain = 320
- Snowstorm = 120
- Blizzards = 30
- Wind Chill = 15

Severe Thunderstorm
- Hailstorm = 225
- Torrential Rain = 240
- Thunderstorm Wind = 225
- Lightning = 150

Tornadoes
- Waterspout = 0

Hurricane/Tropical Storm
- Storm Surge = 0
- High Winds = 30
- Torrential Rain = 300
- Tornadoes = 30

Nor'easters
- High Winds = 0
- Storm Surge = 0
- Severe Winter Weather = 60

Drought
- Hydrological = 180
- Agricultural = 240

Piedmont 5 : 11 Counties
Cleveland
Lincoln
Gaston
Mecklenburg
Cabarrus
Union
Stanly
Anson
Richmond
Moore
Montgomery

Top 5 Hazard Scores
Hurricane = 375
Severe Thunderstorm = 300
Mine Collapse = 300
Dam Failure = 300
Drought = 240
Severe Winter Weather = 240
Expansive Soils = 200
Acidic Soils = 180

Hazard Scores
Severe Winter Weather = 240
Extreme Cold = 5
Severe Thunderstorm = 300
Tornadoes = 100
High Winds = 15
Hurricane/Tropical Storm = 375
Nor'easters = 60
Drought = 240
Heat Wave = 60
Fog = 75
Rip Currents = 0
Avalanche = 0
Debris Flow (Landslide) = 60
Volcanoes = 0
Expansive Soils = 200
Acidic Soils = 180
Subsidence = 150
Mine Collapse = 300
Dam Failure = 300
Sink Holes = 0
Coastal Erosion = 0
Geochemical-related = 150
Tsunami = 0
Wildfire = 150

Hazard Sub-Scores
Severe Winter Weather
- Freezing Rain = 240
- Snowstorm = 120
- Blizzards = 30
- Wind Chill = 15

Severe Thunderstorm
- Hailstorm = 225
- Torrential Rain = 240
- Thunderstorm Wind = 225
- Lightning = 150

Tornadoes
- Waterspout = 0

Hurricane/Tropical Storm
- Storm Surge = 0
- High Winds = 30
- Torrential Rain = 300
- Tornadoes = 30

Nor'easters
- High Winds = 0
- Storm Surge = 0
- Severe Winter Weather = 60

Drought
- Hydrological = 180
- Agricultural = 240

Coastal Plain 6 : 9 Counties

Harnett
Hoke
Cumberland
Scotland
Robeson
Columbus
Bladen
Sampson
Duplin

Top 5 Hazard Scores

Sink Holes = 500
Wildfire = 400
Acidic Soils = 375
Hurricane = 375
Severe Thunderstorm = 300
Subsidence = 250

Hazard Scores

Severe Winter Weather = 160
Extreme Cold = 5
Severe Thunderstorm = 300
Tornadoes = 100
High Winds = 15
Hurricane/Tropical Storm = 375
Nor'easters = 180
Drought = 240
Heat Wave = 80
Fog = 75
Rip Currents = 0
Avalanche = 0
Debris Flow (Landslide) = 0
Volcanoes = 0
Expansive Soils = 120
Acidic Soils = 375
Subsidence = 250
Mine Collapse = 0
Dam Failure = 200
Sink Holes = 500
Coastal Erosion = 0
Geochemical-related = 90
Tsunami = 0
Wildfire = 400

Hazard Sub-Scores

Severe Winter Weather
- Freezing Rain = 160
- Snowstorm = 80
- Blizzards = 30
- Wind Chill = 10

Severe Thunderstorm
- Hailstorm = 225
- Torrential Rain = 240
- Thunderstorm Wind = 225
- Lightning = 200

Tornadoes
- Waterspout = 0

Hurricane/Tropical Storm
- Storm Surge = 0
- High Winds = 90
- Torrential Rain = 300
- Tornadoes = 30

Nor'easters
- High Winds = 40
- Storm Surge = 0
- Severe Winter Weather = 135

Drought
- Hydrological = 180
- Agricultural = 240

Coastal 6 : 4 Counties
Brunswick
New Hanover
Pender
Onslow

Top 5 Hazard Scores
Wildfire = 625
Sink Holes = 500
Hurricane/Tropical Storm = 375
Coastal Erosion = 375
Severe Thunderstorm = 300
Subsidence = 250

Hazard Scores
Severe Winter Weather = 60
Extreme Cold = 5
Severe Thunderstorm = 300
Tornadoes = 100
High Winds = 40
Hurricane/Tropical Storm = 375
Nor'easters = 225
Drought = 240
Heat Wave = 80
Fog = 75
Rip Currents = 100
Avalanche = 0
Debris Flow (Landslide) = 0
Volcanoes = 0
Expansive Soils = 0
Acidic Soils = 25
Subsidence = 250
Mine Collapse = 0
Dam Failure = 40
Sink Holes = 500
Coastal Erosion = 375
Geochemical-related = 45
Tsunami = 125
Wildfire = 625

Hazard Sub-Scores
Severe Winter Weather
- Freezing Rain = 60
- Snowstorm = 30
- Blizzards = 15
- Wind Chill = 10

Severe Thunderstorm
- Hailstorm = 225
- Torrential Rain = 240
- Thunderstorm Wind = 225
- Lightning = 200

Tornadoes
- Waterspout = 25

Hurricane/Tropical Storm
- Storm Surge = 240
- High Winds = 120
- Torrential Rain = 300
- Tornadoes = 30

Nor'easters
- High Winds = 150
- Storm Surge = 120
- Severe Winter Weather = 60

Drought
- Hydrological = 180
- Agricultural = 240

Coastal Plain 7 : 7 Counties

Johnston
Wayne
Wilson
Greene
Lenoir
Pitt
Jones

Top 5 Hazard Scores

Acidic Soils = 375
Hurricane = 375
Severe Thunderstorm = 300
Subsidence = 250
Severe Winter Weather = 240
Drought = 240
Sink Holes = 240
Nor'easters = 180

Hazard Scores

Severe Winter Weather = 240
Extreme Cold = 5
Severe Thunderstorm = 300
Tornadoes = 100
High Winds = 15
Hurricane/Tropical Storm = 375
Nor'easters = 180
Drought = 240
Heat Wave = 80
Fog = 75
Rip Currents = 0
Avalanche = 0
Debris Flow (Landslide) = 0
Volcanoes = 0
Expansive Soils = 120
Acidic Soils = 375
Subsidence = 250
Mine Collapse = 0
Dam Failure = 80
Sink Holes = 240
Coastal Erosion = 0
Geochemical-related = 90
Tsunami = 0
Wildfire = 150

Hazard Sub-Scores

Severe Winter Weather
- Freezing Rain = 240
- Snowstorm = 80
- Blizzards = 30
- Wind Chill = 10

Severe Thunderstorm
- Hailstorm = 225
- Torrential Rain = 240
- Thunderstorm Wind = 225
- Lightning = 200

Tornadoes
- Waterspout = 0

Hurricane/Tropical Storm
- Storm Surge = 0
- High Winds = 90
- Torrential Rain = 300
- Tornadoes = 30

Nor'easters
- High Winds = 40
- Storm Surge = 0
- Severe Winter Weather = 135

Drought
- Hydrological = 180
- Agricultural = 240

Coastal 7 : 5 Counties
Beaufort
Craven
Pamlico
Hyde
Carteret

Top 5 Hazard Scores
Hurricane = 375
Coastal Erosion = 375
Wildfire = 375
Severe Thunderstorm = 300
Subsidence = 250
Sink Holes = 240
Drought = 240
Nor'easters = 225

Hazard Scores
Severe Winter Weather = 120
Extreme Cold = 5
Severe Thunderstorm = 300
Tornadoes = 100
High Winds = 40
Hurricane/Tropical Storm = 375
Nor'easters = 225
Drought = 240
Heat Wave = 80
Fog = 75
Rip Currents = 100
Avalanche = 0
Debris Flow (Landslide) = 0
Volcanoes = 0
Expansive Soils = 0
Acidic Soils = 25
Subsidence = 250
Mine Collapse = 0
Dam Failure = 40
Sink Holes = 240
Coastal Erosion = 375
Geochemical-related = 45
Tsunami = 125
Wildfire = 375

Hazard Sub-Scores
Severe Winter Weather
- Freezing Rain = 120
- Snowstorm = 30
- Blizzards = 15
- Wind Chill = 10

Severe Thunderstorm
- Hailstorm = 225
- Torrential Rain = 240
- Thunderstorm Wind = 225
- Lightning = 200

Tornadoes
- Waterspout = 25

Hurricane/Tropical Storm
- Storm Surge = 240
- High Winds = 120
- Torrential Rain = 300
- Tornadoes = 30

Nor'easters
- High Winds = 150
- Storm Surge = 225
- Severe Winter Weather = 60

Drought
- Hydrological = 180
- Agricultural = 240

Coastal Plain 8 : 5 Counties

Nash
Halifax
Northampton
Edgecombe
Martin

Top 5 Hazard Scores

Hurricane = 375
Wildfire = 300
Severe Thunderstorm = 300
Drought = 240
Severe Winter Weather = 240
Nor'easters = 180
Subsidence = 150

Hazard Scores

Severe Winter Weather = 240
Extreme Cold = 5
Severe Thunderstorm = 300
Tornadoes = 100
High Winds = 15
Hurricane/Tropical Storm = 375
Nor'easters = 180
Drought = 240
Heat Wave = 80
Fog = 75
Rip Currents = 0
Avalanche = 0
Debris Flow (Landslide) = 0
Volcanoes = 0
Expansive Soils = 120
Acidic Soils = 20
Subsidence = 150
Mine Collapse = 0
Dam Failure = 15
Sink Holes = 0
Coastal Erosion = 0
Geochemical-related = 90
Tsunami = 0
Wildfire = 300

Hazard Sub-Scores

Severe Winter Weather
- Freezing Rain = 240
- Snowstorm = 80
- Blizzards = 30
- Wind Chill = 10

Severe Thunderstorm
- Hailstorm = 225
- Torrential Rain = 240
- Thunderstorm Wind = 225
- Lightning = 150

Tornadoes
- Waterspout = 0

Hurricane/Tropical Storm
- Storm Surge = 0
- High Winds = 90
- Torrential Rain = 300
- Tornadoes = 30

Nor'easters
- High Winds = 40
- Storm Surge = 0
- Severe Winter Weather = 135

Drought
- Hydrological = 180
- Agricultural = 240

Coastal 8 : 11 Counties
Gates
Hertford
Bertie
Chowan
Perquimans
Pasquotank
Camden
Currituck
Washington
Tyrrell
Dare

Top 5 Hazard Scores
Hurricane = 375
Coastal Erosion = 375
Severe Thunderstorm = 300
Wildfire = 250
Drought = 240
Nor'easters = 225

Hazard Scores
Severe Winter Weather = 120
Extreme Cold = 5
Severe Thunderstorm = 300
Tornadoes = 100
High Winds = 40
Hurricane/Tropical Storm = 375
Nor'easters = 225
Drought = 240
Heat Wave = 80
Fog = 75
Rip Currents = 100
Avalanche = 0
Debris Flow (Landslide) = 0
Volcanoes = 0
Expansive Soils = 0
Acidic Soils = 20
Subsidence = 150
Mine Collapse = 0
Dam Failure = 30
Sink Holes = 0
Coastal Erosion = 375
Geochemically-related = 45
Tsunami = 125
Wildfire = 250

Hazard Sub-Scores
Severe Winter Weather
- Freezing Rain = 120
- Snowstorm = 30
- Blizzards = 15
- Wind Chill = 10

Severe Thunderstorm
- Hailstorm = 225
- Torrential Rain = 240
- Thunderstorm Wind = 225
- Lightning = 150

Tornadoes
- Waterspout = 25

Hurricane/Tropical Storm
- Storm Surge = 240
- High Winds = 120
- Torrential Rain = 300
- Tornadoes = 30

Nor'easters
- High Winds = 150
- Storm Surge = 225
- Severe Winter Weather = 60

Drought
- Hydrological = 180
- Agricultural = 240

12 APPENDIX E: EXPOSURE SCORE ASSIGNMENTS

Indicator	Min	Max	Max - Min	Div by 5	No decimals	Indicator	Min	Range1	Range2	Range3	Range4	Range5
Population indicator												
sum-population	4149	695454	691305	138261	138261	sum-population	4149	142410	280671	418932	557193	695454
Structural Exposure indicators												
sum-builtinoraft	382	97287	96905	19381	19381	sum-builtinoraft	382	19763	39144	58525	77906	97287
sum-builtbefore7	838	90057	89219	17843.8	17844	sum-builtbefore7	838	18682	36526	54369	72213	90057
sum-builtb70to90	733	107157	106424	21284.8	21285	sum-builtb70to90	733	22018	43303	64587	85872	107157
sum-gov1l	0	128	128	25.6	26	sum-gov1l	0	26	51	77	102	128
sum-gov2l	0	14	14	2.8	3	sum-gov2l	0	3	6	8	11	14
sum-res_all	1495	400931	399436	79887.2	79887	sum-res_all	1495	81382	161269	241157	321044	400931
sum-com_all	4	4365	4361	872.2	872	sum-com_all	4	876	1748	2621	3493	4365
sum-ind_all	0	679	679	135.8	136	sum-ind_all	0	136	272	407	543	679
sum-agr_all	0	17	17	3.4	3	sum-agr_all	0	3	7	10	14	17
sum-rel_all	1	178	177	35.4	35	sum-rel_all	1	36	72	107	143	178
sum-edu_all	0	31	31	6.2	6	sum-edu_all	0	6	12	19	25	31
Critical Facilities Exposure indicators												
sum-damscgiah_#	1	106	105	21	21	sum-damscgiah_#	1	22	43	64	85	106
sum-nuclear_#	0	1	1	0.2	0	sum-nuclear_#	0	0	0	0	0	1
sum-militcgia_#	0	3	3	0.6	1	sum-militcgia_#	0	1	0	2	0	3
sum-gov2l	0	14	14	2.8	3	sum-gov2l	0	3	6	8	11	14
sum-hospitall_#	0	5	5	1	1	sum-hospitall_#	0	1	2	3	4	5
sum-emergctr_#	1	2	1	0.2	0	sum-emergctr_#	0	0	0	1	0	2
sum-damscgiai_#	0	51	51	10.2	10	sum-damscgiai_#	0	10	20	31	41	51
sum-electric_#	0	8	8	1.6	2	sum-electric_#	0	2	3	5	6	8
sum-natgas_#	0	1	1	0.2	0	sum-natgas_#	0	0	0	0	0	1
sum-hospitalm_#	0	6	6	1.2	1	sum-hospitalm_#	0	1	2	4	5	6
sum-hospitallm_#	0	9	9	1.8	2	sum-hospitallm_#	0	2	4	5	7	9
sum-commun_#	0	25	25	5	5	sum-commun_#	0	5	10	15	20	25
sum-police_#	1	25	24	4.8	5	sum-police_#	1	6	11	15	20	25

Indicator	Min	Max	Max - Min	Div by 5	No decimals	Indicator	Min	Range1	Range2	Range3	Range4	Range5
Crit. Fac. (cont.)												
sum-fire_#	0	44	44	8.8	9	sum-fire_#	0	9	18	26	35	44
sum-wwtp_#	0	86	86	17.2	17	sum-wwtp_#	0	17	34	52	69	86
sum-potableh2o_#	0	10	10	2	2	sum-potableh2o_#	0	2	4	6	8	10
sum-hospital_s_#	0	2	2	0.4	0	sum-hospital_s_#	0	0	0	1	0	2
sum-damscgial_#	0	206	206	41.2	41	sum-damscgial_#	0	41	82	124	165	206
Economic Activity Exposure indicators												
mhh_income	25177	54988	29811	5962.2	5962	mhh_income	25177	31139	37101	43064	49026	54988
poverty	7	24	17	3.4	3	poverty	7	10	14	17	21	24
employ_gov	423	69902	69479	13895.8	13896	employ_gov	423	14319	28215	42110	56006	69902
employ_ag	0	3235	3235	647	647	employ_ag	0	647	1294	1941	2588	3235
employ_edu	0	31493	31493	6298.6	6299	employ_edu	0	6299	12597	18896	25194	31493
employ_ind	79	69698	69619	13923.8	13924	employ_ind	79	14003	27927	41850	55774	69698
employ_com	465	337643	337178	67435.6	67436	employ_com	465	67901	135336	202772	270207	337643
Transportation Exposure indicators												
sum-airports_#	0	13	13	2.6	3	sum-airports_#	0	3	5	8	10	13
sum-buses_#	0	4	4	0.8	1	sum-buses_#	0	1	2	2	3	4
sum-bridges_#	11	489	478	95.6	96	sum-bridges_#	11	107	202	298	393	489
sum-tunnels_#	0	3	3	0.6	1	sum-tunnels_#	0	1	1	2	2	3
sum-ports_#	0	33	33	6.6	7	sum-ports_#	0	7	13	20	26	33
sum-railroads_#	0	17	17	3.4	3	sum-railroads_#	0	3	7	10	14	17
Environmental Exposure indicators												
sum-anop_#	0	490	490	98	98	sum-anop_#	0	98	196	294	392	490
sum-npdes_#	0	27	27	5.4	5	sum-npdes_#	0	5	11	16	22	27
sum-hazmat_#	0	274	274	54.8	55	sum-hazmat_#	0	55	110	164	219	